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**MISSION SERVICES PROGRAM OFFICE**

# Ground Network (GN) Users' Guide

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National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

# Ground Network Users' Guide

**Original**

**May 2003**

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The contents of this document have been revised and supersede the Ground Network Users' Guide, 452-GNUG-GN, dated February 2001, and all changes thereto. Destroy any previously issued copies.

**Goddard Space Flight Center**
Greenbelt, Maryland

# Preface

This document is under the configuration management of Code 453, Ground Network Project Office Configuration Control Board (CCB).

Proposed changes to this document should be submitted to the Ground Network Project Office along with supportive material justifying the change. Changes to this document shall be made by document change notice (DCN) or by complete revision. Questions and proposed changes concerning this document shall be addressed to:

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# Section 1. Introduction

## 1.1 Purpose

The purpose of this document is to describe the technical capabilities of the ground stations that comprise the National Aeronautics and Space Administration (NASA) Ground Network (GN).

This document provides sufficient information to enable project engineers and support personnel to begin interfacing with the GN. It is not intended to be a technical description of network equipment; rather, it defines GN capabilities and identifies those parameters of particular interest to the user. For more detailed information, see the documents cited in Section 1.3.

Because GN capabilities may change (due to budgetary constraints or management decisions, for example), the information presented in this document does not obligate NASA in any way.

## 1.2 Scope

For the purpose of this document, the GN consists of NASA ground stations located in Norway, Florida, Alaska, Antarctica, and the Wallops Flight Facility (WFF) in Virginia. The GN also includes support from the Network Integration Center (NIC) located at GSFC and the Data Services Management Center and VHF systems at the White Sands Complex, New Mexico.

For each GN station, this document provides the following information:

- General characteristics, including geographic location, transmit/receive capabilities, and scheduling capabilities.
- Detailed performance characteristics.
- User tracking capabilities.
- Baseband data interfaces.

Detailed information on frequency management considerations and link budget parameters is also provided.

## 1.3 Reference Documents

The following documents are referenced herein and/or provide background information:

a. EOS Polar Ground Station Project Phase I Functional and Performance Requirements, 452-F&PR1-EPGS, May 1998.

b. NASA/GSFC/WFF Ground Network Resources, GSFC, WFF, October 1997.

c. Tracking and Data Acquisition System Capabilities, Revision 5.1, GSFC, WFF, December 1992.

d. Consultative Committee for Space Data Systems, Radio Frequency and Modulation Systems, Part 1, Earth Stations, CCSDS 411401.0-G-3, Green Book, May 1997B, June 2001.

e. NISN Services Document (NSD), NISN 001-001 (Rev. 4-C).

f. NASA Communications (NASCOM) Operating Procedures (NASCOP), 542-006-V2, Section 5, November 1995.

g. Earth Observing System (EOS) Data and Information System (EOSDIS) Backbone Network (EBnet) Operations Concept, 540-028, Revision 1, GSFC, May 1996.

h. Programmable Telemetry Processor for Windows NT, User's Manual, Version 1.34, TR 97-08-01, July 1998.

i. NASA Communications (NASCOM) Internet Protocol (IP) Transition Operations Concepts Document, 541-230, GSFC, September 1996.

j. Wallops Capability Matrix, WFF, Microwave Systems Branch, Daniel A. Mullinix, Code 567, 23 February 1998.

k. GN Compatibility Matrix,Version 5, July 2001.

l. Operations Interface Procedures Between the Network Control Center and Spaceflight Tracking and Data Network Users, 534-OIP-NCC/STDN.

m. Network Capability Matrix, TDA/DSN No. 890-260, JPL Doc. No. D-11090, August 11, 1993.

n. NASA Policy Directive (NPD) 2570.5B, Radio Frequency Spectrum.

o. Tracking and Acquisition Handbook for the Spaceflight Tracking and Data Network, GSFC, 450-TAH-STDN, October 1994

p. NASA Radio Frequency (RF) Spectrum Management Manual, NHB 2570.6B.

q. NTIA Manual of Regulations & Procedures for Federal Radio Frequency Management.

r. ISO/DIS 13420, Consultative Committee for Space Data Systems, , Advanced Orbiting Systems, Networks and Data Links: Architectural Specification, CCSDS 701.0-B, June 2001.

s. Interface Control Document Between Landsat 7 and the Landsat 7 Ground Network (LGN), GSFC, 430-14-01-001-0, September 1997.

t. Data and Computer Communications, 4th Edition, William Stallings, Prentice Hall, 1994.

u. E-mail message from Steve Kremer to Frank Stocklin, "ICESat Characterization Test," 19 January 1999.

v. Radio Frequency (RF) Interface Control Document (ICD) Between the ICESat Spacecraft and the EOS Polar Ground Station (EPGS), Networks and Mission Services Project, GSFC, August 1999.

w. Efficient Spectrum Utilization for Space Science Services on Space-To-Earth Links, SFCG Recommendation 17-2R1, 17 September 1998.

x. Wallops Flight Facility Range User's Handbook, 840-HDBK-0001, Version D, dated April 2003.

y. 450-Catalog-Services, GSFC Mission and Data Services 2003 Catalog.

## 1.4 Document Organization

The remaining portions of this document are organized as follows:

Section 2 provides an overview of the entire GN.

Section 3 describes the Norway ground station (SGS).

Section 4 describes the WFF ground stations in Virginia.

Section 5 describes the McMurdo Ground Station in Antarctica.

Section 6 describes the Alaska ground stations.

Section 7 describes the Florida ground stations.

Section 8 describes the White Sands Complex VHF ground stations.

Section 9 describes the scheduling process.

Section 10 describes baseband data interfaces.

Section 11 describes frequency management considerations.

Section 12 describes link budget parameters.

Appendix A is the acronym list.

# Section 2. Ground Network Overview

This section provides an overview of the GN stations and describes general characteristics of their tracking, telemetry, and command functions. *Table 2-1* summarizes general capabilities and Table 2-2 identifies the command and telemetry capabilities of each station.

To help a flight project select the appropriate GN station(s) on the basis of frequency bands and data rates supported, the following two tables are provided:

- *Table 2-3* – Telemetry support (sorted by frequency band and data rate).
- Table 2-4 – Command support (sorted by frequency band and data rate).

The last part of this section describes the process for obtaining GN services.

## 2.1 EPGS (Norway and Alaska)

The Earth Observing System (EOS) Polar Ground Stations (EPGS) project consists of two high-latitude multi-mission ground stations. The Alaska Ground Station (AGS) is located at the Poker Flat Research Range near Fairbanks, Alaska. The Svalbard Ground Station (SGS) is located in Norway on Spitsbergen, the main island in the Svalbard archipelago. Each station supports S-band command and telemetry and X-band telemetry.

Both EPGS stations have automated components, and are scheduled and monitored from the DSMC at the White Sands Complex.

## 2.2 WFF Ground Stations (Virginia)

### 2.2.1 Orbital Stations

The primary orbital assets at WFF consist of the following system:

- 11.3 meter system
- Low Earth Orbiter-Terminal (LEO-T) – WFF
- Transportable Orbital Tracking System (TOTS) – WFF
- 9 meter system.

WOTIS performs scheduling for all these systems. The characteristics of the systems are briefly described below.

#### 2.2.1.1 11.3 Meter System

WGS supports S-band command and telemetry and X-band telemetry.

**Table 2-1.** ***GN Overview***

| Station | Antenna Diameter | Transmit Frequency (MHz) | EIRP (dBWi) | Receive Frequency (MHz) | G/T (dB/K) | Location | User Tracking |
|---|---|---|---|---|---|---|---|
| **SGS (Norway)** | 11.3 m | 2025-2120 | 66 | 2200-2400<br>8000-9000 | 23<br>35.4 | 78°N 15°E | 1- & 2-Way Dop, Angle |
| **11.3-m System (WFF)** | 11.3 m | 2025-2120 | 66 | 2200-2400<br>8000-9000 | 23<br>35 | 38°N 75°W | 1- & 2-Way Dop, Angle |
| **LEO-T (WFF)** | 5 m | 2025-2120 | 59 | 2200-2300 | 17 | 38°N 75°W | — |
| **TOTS (WFF)** | 8 m | 2025-2120 | 62 | 2200-2400 | 21 | 38°N 75°W | 1- & 2-Way Dop, Angle |
| **9-m System (WFF)** | 9 m | 2025-2120 | 66 | 2200-2300 | 24 | 38°N 75°W | 1- & 2-Way Dop, Range, (Angle TBD) |
| **MGTAS (WFF)** | 7.3 m (2) | — | — | 1435-1535<br>1670-1720<br>2200-2400 | 11<br>12.5<br>15.5 | 38°N 75°W | 1-Way Dop, Range, Angle |
| **SATAN (WFF)** | Arrays (3) | 147-155 | 59 | 136-138 | -7.03 | 38°N 75°W | Range |
| **SCAMP (WFF)** | Array | 147-155 | 57 | — | — | 38°N 75°W | Range (with SATAN) |
| **METEOSAT (WFF)** | 7.3 m | — | — | 1685-1710 | 12 | 38°N 75°W | — |
| **18 Foot Mobile System** | 5.5 m | — | — | 1435-1535<br>1615-1720<br>2200-2300 | 9.4<br>11.6<br>14.6 | Varies | Angle |
| **20 Foot Mobile System** | 6.1 m | — | — | 1435-1535<br>1615-1720<br>2200-2400 | 10.3<br>12.5<br>15.5 | Varies | Angle |
| **10 Foot Mobile System** | 3.0 m | — | — | 1435-1535<br>1615-1720<br>2200-2300 | 4.1<br>5.1<br>8.0 | Varies | Angle |
| **8 Foot Mobile System** | 2.4 m | — | — | 1435-1535<br>1615-1720<br>2200-2300 | 3.3<br>4.5<br>7.0 | Varies | Angle |

## Table 2-1. *GN Overview* (cont'd)

| Station | Antenna Diameter | Transmit Frequency (MHz) | EIRP (dBWi) | Receive Frequency (MHz) | G/T (dB/K) | Location | User Tracking |
|---|---|---|---|---|---|---|---|
| **23 Foot Mobile System** | 7.0 m | — | — | 1435-1535<br>1615-1720<br>2200-2400 | 12.0<br>13.7<br>20.0 | Varies | Angle |
| **Fixed UHF Command System** | Quad Helix (2) | 410-450 | 46 | — | — | 38°N 76°W | — |
| **Mobile UHF Command System** | Single Helix (2) | 410-450 | 43 | — | — | Varies | — |
| **RADARs** | | | | | | | |
| **ASRF** | 18.3 m | UHF-Band | 69 | UHF-Band | — | 38°N 76°W | — |
| **Spander** | 18.3 m | S-Band | 67 | S-Band | — | 38°N 76°W | — |
| **AN/ASR-7** | 5.3x2.7 m | S-Band | 56 | S-Band | — | 38°N 75°W | — |
| **Marine Pathfinder** | 3.7x0.15 m | X-Band | 43 | X-Band | — | 38°N 75°W | — |
| **Radar #3** | 3.66 m | C-Band | 60 | C-Band | — | 38°N 75°W | — |
| **Radar #5** | 8.84 m | C-Band | 65 | C-Band | — | 38°N 76°W | — |
| **Radar #18** | 4.88 m | C-Band | 60 | C-Band | — | 38°N 75°W | — |
| **Radar #2** | 2.38 m | C-Band | 60 | C-Band | — | Varies | — |
| **Radar #8** | 2.38 m | C-Band | 60 | C-Band | — | Varies | — |
| **Radar #10** | 3.66 m | C-Band | 60 | C-Band | — | Varies | — |
| **Radar #11** | 3.66 m | C-Band | 60 | C-Band | — | Varies | — |

## Table 2-1. *GN Overview* (cont'd)

| Station | Antenna Diameter | Transmit Frequency (MHz) | EIRP (dBWi) | Receive Frequency (MHz) | G/T (dB/K) | Location | User Tracking |
|---|---|---|---|---|---|---|---|
| **WFF VHF-1 Ground Station** | N/A (Yagi) | 139.208 | 45.4 | 143.625 | TBD | 38°N 75°W | None |
| **WFF VHF-2 Ground Station** | N/A (Yagi) | 130.167 | 45.4 | 121.750 | TBD | 38°N 75°W | None |
| **MGS (Antarctica)** | 10 m | 2025-2120 | 63 | 2200-2400<br>8025-8400 | 21.1<br>32.5 | 78°S 193°W | — |
| **LEO-T (Alaska)** | 5 m | 2025-2120 | 59.2 | 2200-2300 | 17 | 65°N 147°W | — |
| **TOTS (Alaska)** | 8 m | 2025-2120 | 62 | 2200-2400 | 21 | 65°N 147°W | 1- & 2-Way Dop, Angle |
| **AGS (Alaska)** | 11.3 m | 2025-2120 | 66 | 2200-2400<br>8000-9000 | 23<br>36 | 65°N 147°W | 1- & 2-Way Dop, Angle |
| **MILA (Florida)** | 9 m (2) | 2025-2120 | 63 | 2200-2300 | 24 | 29°N 81°W | 1- & 2-Way Dop, Range, Angle |
| **PDL (Florida)** | 4.3 m | 2025-2120 | 58 | 2200-2300 | 11 | 29°N 81°W | — |
| **WSC VHF-1 Ground Station** | N/A (Yagi) | 139.208 | 43.4 | 143.625 | TBD | 32°N 106°E | None |
| **WSC VHF-2 Ground Station** | N/A (Yagi) | 130.167 | 45.4 | 121.750 | TBD | 32°N 106°E | None |

**Table 2-2.** ***Command and Telemetry Support by Station***

| Station | Data Type | Band | Carrier or Subcarrier | Maximum Data Rate | Coding |
|---|---|---|---|---|---|
| EPGS (SGS and AGS) | Command | S-band | Carrier | 200 kbps | — |
| | | | Subcarrier | 32 kbps | |
| | Telemetry | S-band | Carrier | 8 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1 Mbps | |
| | | X-band | Carrier | 150 Mbps | Viterbi and/or R-S |
| WGS | Command | S-band | Carrier | 200 kbps | — |
| | | | Subcarrier | 32 kbps | — |
| | Telemetry | S-band | Carrier | 8 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1 Mbps | |
| | | X-band | Carrier | 110 Mbps | |
| LEO-T (WFF) | Command | S-band | Carrier | 200 kbps | — |
| | | | Subcarrier | 32 kbps | |
| | Telemetry | S-band | Carrier | 8 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1 Mbps | |
| TOTS (WFF) | Command | S-band | Carrier | 200 kbps | — |
| | | | Subcarrier | 32 kbps | |
| | Telemetry | S-band | Carrier | 5 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1 Mbps | |
| 9-m System (WFF) | Command | S-band | Carrier | 5 Mbps | — |
| | | | Subcarrier | 2 kbps | |
| | Telemetry | S-band | Carrier | 15 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1 Mbps | |
| MGTAS | Telemetry | L-band | Carrier | 6.6 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1.3 Mbps* | |
| | | S-band | Carrier | 6.6 Mbps | |
| | | | Subcarrier | 1.3 Mbps* | |

* The data rate of the telemetry subcarrier must be less than $2/3$ the frequency of the subcarrier.

Table 2-2. Command and Telemetry Support by Station (cont'd)

| Station | Data Type | Band | Carrier or Subcarrier | Maximum Data Rate | Coding |
|---|---|---|---|---|---|
| SATAN | Command | VHF | Carrier | 20 kbps | — |
| | | | Subcarrier | 2 kbps | |
| | Telemetry | VHF | Carrier | 10 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1.3 Mbps* | |
| SCAMP | Command | VHF | Carrier | 20 kbps | — |
| | | | Subcarrier | 2 kbps | |
| METEOSAT | Telemetry | L-band | Carrier | 6.6 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1.3 Mbps* | |
| 18 Foot Mobile System | Telemetry | L-band | Carrier | 4.0 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1.3 Mbps* | |
| | | S-band | Carrier | 4.0 Mbps | Viterbi |
| | | | Subcarrier | 1.3 Mbps* | |
| 20 Foot, 10 Foot, and 8 Foot Mobile Systems | Telemetry | L-band | Carrier | 4.0 Mbps | Viterbi |
| | | | Subcarrier | 1.3 Mbps* | |
| | | S-band | Carrier | 4.0 Mbps | Viterbi |
| | | | Subcarrier | 1.3 Mbps* | |
| 23 Foot Mobile System | Telemetry | L-band | Carrier | 4.0 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1.3 Mbps* | |
| | | S-band | Carrier | 4.0 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1.3 Mbps* | |
| Fixed UHF Command System | Command | UHF band | Carrier | IRIG Standard Tones | — |
| Mobile UHF Command System | Command | UHF band | Carrier | IRIG Standard Tones | — |

* The data rate of the telemetry subcarrier must be less than 2/3 the frequency of the subcarrier.

Table 2-2. Command and Telemetry Support by Station (cont'd)

| Station | Data Type | Band | Carrier or Subcarrier | Maximum Data Rate | Coding |
|---|---|---|---|---|---|
| MGS | Command | S-band | Carrier | 200 kbps | — |
| | | | Subcarrier | 32 kbps | — |
| | Telemetry | S-band | Carrier | 8 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1 Mbps | Viterbi and/or R-S |
| | | X-band | Carrier | 110 Mbps | Viterbi and/or R-S |
| LEO-T (Alaska) | Command | S-band | | 200 kbps | — |
| | | | Subcarrier | 32 kbps | — |
| | Telemetry | S-band | Carrier | 8 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1 Mbps | Viterbi and/or R-S |
| TOTS (Alaska) | Command | S-band | Carrier | 200 kbps | — |
| | | | Subcarrier | 32 kbps | — |
| | Telemetry | S-band | Carrier | 4 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1 Mbps | Viterbi and/or R-S |
| MILA | Command | S-band | Carrier | 216 kbps | — |
| | | | Subcarrier | 8 kbps | — |
| | Telemetry | S-band | Carrier | 10 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 2 Mbps | Viterbi and/or R-S |
| PDL | Command | S-band | Carrier | — | — |
| | | | Subcarrier | 8 kbps | — |
| | Telemetry | S-band | Carrier | 2 Mbps | Viterbi and/or R-S |
| | | | Subcarrier | 1.3 Mbps* | Viterbi and/or R-S |

* The data rate of the telemetry subcarrier must be less than $^2/_3$ the frequency of the subcarrier.

**Table 2-3.** ***Telemetry Support – Sorted by Frequency Band and Data Rate***

| Band | Maximum Data Rate | Carrier or Subcarrier | Coding | Station |
|---|---|---|---|---|
| S-band | 10 Mbps | Carrier | Viterbi and/or R-S | MILA |
| | 2 Mbps | Subcarrier | Viterbi and/or R-S | |
| | 8 Mbps | Carrier | Viterbi and/or R-S | EPGS (SGS and AGS)<br>WGS<br>MGS<br>LEO-T (WFF and Alaska) |
| | 1 Mbps | Subcarrier | Viterbi and/or R-S | |
| | 6.6 Mbps | Carrier | Viterbi and/or R-S | MGTAS |
| | 1.3 Mbps* | Subcarrier | Viterbi and/or R-S | |
| | 5 Mbps | Carrier | Viterbi and/or R-S | TOTS (WFF) |
| | 1 Mbps | Subcarrier | Viterbi and/or R-S | |
| | 4 Mbps | Carrier | Viterbi | 18 Foot, 20 Foot,<br>10 Foot, and 8 Foot Mobile Systems |
| | 1.3 Mbps* | Subcarrier | Viterbi | |
| | 4 Mbps | Carrier | Viterbi and/or R-S | 23 Foot Mobile System |
| | 1.3 Mbps* | Subcarrier | Viterbi and/or R-S | |
| | 4 Mbps | Carrier | Viterbi and/or R-S | TOTS (Alaska) |
| | 1 Mbps | Subcarrier | Viterbi and/or R-S | |
| | 2 Mbps | Carrier | Viterbi and/or R-S | PDL |
| | 1.3 Mbps* | Subcarrier | Viterbi and/or R-S | |

*Table 2-3*. **Telemetry Support – Sorted by Frequency Band and Data Rate (cont'd)**

| Band | Maximum Data Rate | Carrier or Subcarrier | Coding | Station |
|---|---|---|---|---|
| X-band | 150 Mbps | Carrier | Viterbi and/or R-S | EPGS (SGS and AGS) |
| | 110 Mbps | Carrier | Viterbi and/or R-S | WGS<br>MGS |
| L-band | 6.6 Mbps | Carrier | Viterbi and/or R-S | METEOSAT<br>MGTAS |
| | 1.3 Mbps* | Subcarrier | Viterbi and/or R-S | |
| | 4 Mbps | Carrier | Viterbi and/or R-S | 18 Foot and 23 Foot Mobile Systems |
| | 1.3 Mbps* | Subcarrier | Viterbi and/or R-S | |
| | 4 Mbps | Carrier | Viterbi | 20 Foot, 10 Foot, and 8 Foot Mobile Systems |
| | 1.3 Mbps* | Subcarrier | Viterbi | |
| VHF | 10 Mbps | Carrier | Viterbi and/or R-S | SATAN (WFF) |
| | 1.3 Mbps* | Subcarrier | Viterbi and/or R-S | |

* The data rate of the telemetry subcarrier must be less than $^2/_3$ the frequency of the subcarrier.

**Table 2-4.** ***Command Support – Sorted by Frequency Band and Data Rate***

| Band | Maximum Data Rate | Carrier or Subcarrier | Station |
|---|---|---|---|
| S-band | 216 kbps | Carrier | MILA |
| | 8 kbps | Subcarrier | |
| | 200 kbps | Carrier | EPGS (SGS/AGS)<br>WGS<br>MGS<br>LEO-T (WFF)<br>TOTS (WFF)<br>LEO-T (Alaska)<br>TOTS (Alaska) |
| | 32 kbps | Subcarrier | |
| VHF | 20 kbps | Carrier | SATAN (WFF)<br>SCAMP |
| | 2 kbps | Subcarrier | |
| | TBD | Carrier | ISS (WFF and WSC) |
| | — | Subcarrier | |
| UHF | IRIG Standard Tones | Carrier | UHF Command Systems (WFF) |

#### 2.2.1.2 LEO-T – WFF

The LEO-T station at WFF supports S-band command and telemetry.

#### 2.2.1.3 TOTS – WFF

The TOTS station at WFF supports S-band command and telemetry.

#### 2.2.1.4 9 Meter system

The 9 meter system at WFF supports S-band command and telemetry.

### 2.2.2 Other WFF Ground Stations

In addition, the following ground stations are also located at WFF:

- Medium Gain Telemetry Antenna System (MGTAS)
- Satellite Automatic Tracking Antenna (SATAN)
- Small Command Antenna on a Medium Pedestal (SCAMP)
- Meteorological Satellite (METEOSAT)
- 18 Foot, 20 Foot, 10 Foot, 8 Foot, and 23 Foot Mobile Systems
- UHF Command Systems
- Radar Systems
- VHF Ground Stations.

These stations support tracking and data acquisition for NASA-approved missions, as well as range safety operations for high-inclination launches from the Kennedy Space Center (KSC), including the Space Shuttle. The characteristics of the stations are briefly described below.

#### 2.2.2.1 MGTAS

MGTAS supports only telemetry at S- and L-band. WOTIS provides automated scheduling.

#### 2.2.2.2 SATAN

SATAN has three VHF antenna arrays: one for transmit and two for receive. It supports VHF command and telemetry. The user, DSMC, and ground station personnel schedule the station via e-mail and telephone.

#### 2.2.2.3 SCAMP

SCAMP supports only VHF commanding. When used with the receive portion of SATAN, SCAMP can support range tracking. The user, DSMC, and ground station personnel schedule the station via e-mail and telephone.

#### 2.2.2.4 METEOSAT

METEOSAT supports only L-band telemetry. The user, DSMC, and ground station personnel schedule the station via e-mail and telephone.

#### 2.2.2.5 Mobile Systems

The 18 Foot, 20 Foot, 10 Foot, 8 Foot, and 23 Foot Mobile Systems support L-band and S-band telemetry. The user, WFF Range and Mission Management Office, and mobile system personnel schedule each mobile system via e-mail and telephone.

#### 2.2.2.6 UHF Command Systems

The Fixed UHF Command System and Mobile UHF Command System support the transmission of specific flight termination commands (arm/destruct/terminate) and other types of commands, such as, control of events and guidance. The user and WFF Range and Mission Management Office schedule each mobile system via e-mail and telephone.

#### 2.2.2.7 Radar Systems

The seven Fixed Radar Systems and four Mobile Radar Systems provide tracking services. The user and WFF Radar coordinator schedule each mobile system via e-mail and telephone.

#### 2.2.2.8 VHF Ground Stations

The WFF VHF Air/Ground (A/G) Ground Stations are used only to support the International Space Station and Soyuz spacecraft. The VHF-1 system can transmit and receive voice and support packet data on the uplink. The VHF-2 system supports only voice.

## 2.3 McMurdo Ground Station (MGS) (Antarctica)

McMurdo Ground Station (MGS) is located at McMurdo Station in Antarctica. It supports S-band command and telemetry and X-band telemetry. WOTIS provides automated scheduling.

## 2.4 Alaska Ground Stations

In addition to the AGS discussed in Section 2.1 above, the Poker Flat Research Range contains two other ground stations: LEO-T – Alaska and TOTS – Alaska. These stations are located 30 miles northeast of Fairbanks. The characteristics of the two stations are briefly described below.

### 2.4.1 LEO-T – Alaska

The LEO-T station in Alaska supports S-band command and telemetry. WOTIS provides automated scheduling.

### 2.4.2 TOTS – Alaska

The TOTS station in Alaska supports S-band command and telemetry. The user, DSMC, and ground station personnel perform scheduling via e-mail and telephone.

## 2.5 Florida Ground Stations

There are two GN stations in Florida: Merritt Island Launch Area (MILA) and Ponce De Leon (PDL). They primarily support Space Shuttle launches and landings. MILA and PDL support S-band command and telemetry. The DSMC, located at the White Sands Complex in New Mexico, schedules both stations.

## 2.6 White Sands Complex VHF Ground Stations

The White Sands Complex (WSC) VHF Air/Ground (A/G) Ground Stations are located near Las Cruces, New Mexico. They are used only to support the International Space Station and Soyuz spacecraft. The VHF-1 system can transmit and receive voice and support packet data on the uplink. The VHF-2 system supports only voice.

## 2.7 Analysis, Test, and Simulation Support

The Missions Services Program Office performs analysis, testing, and simulation which are of direct benefit to the user flight project. Some are mandatory to validate compatibility and to meet launch readiness requirements. Analysis will address such preliminary questions as projected GN loading, RF link margins, geometric coverage analyses, and Missions Services Program Office preliminary funding and manpower requirements. The results of such analyses will enable an early assessment of the project's compatibility with the GN, and other analyses or information pertaining to other GN elements.

### 2.7.1 Network Loading Analysis

To ensure that sufficient GN resources are available to meet commitments to current and future users, the Missions Services Program Office provides a representative to each user flight project as early as possible during mission planning to assist in the definition of user flight project needs for Missions Services Program Office services. Typical information needed are the projected requirements for communications timeline, data rates, and number of data channels. Although this information may initially be of a preliminary nature, the best available information is needed for projecting GN loading.

### 2.7.2 RF Link Margin and Coverage Analysis

Information exchange for the RF link margin and coverage analysis begins during the initial flight segment mission analysis phase and continues until firm coverage requirements and flight segment designs are finalized in the mission execution phase. The Communications Link Analysis and Simulation System (CLASS) analysis tool can be used to help achieve a flight segment telecommunications design which is compatible with the GN, and will achieve the desired level of performance. Design deficiencies and possible trade-offs are defined during these analyses. The results of CLASS are used early in the mission analysis phase to aid in the development of the RF Interface Control Document (ICD), which is a controlling input to the flight segment telecommunications specifications.

### 2.7.3 Compatibility Testing

Compatibility testing is performed as early as possible after fabrication of the user spacecraft (either the flight model, which is preferred, or the prototype model) is completed. Compatibility tests are normally rerun following resolution of significant problems encountered during the original test or following posttest flight segment design modification. Results of these tests are formally published in the mission-specific Compatibility Test Report. Satisfactory completion of this testing and certification is required to meet the Missions Services Program Office readiness-for-launch criteria.

### 2.7.4 GN Interface Testing and Operational Simulations

Mutually agreed upon end-to-end tests are conducted to validate all telecommunications system functions, as defined in the applicable ICDs. In addition, operational exercises (i.e., simulations, data flows) are conducted to ensure that operations will satisfy requirements and timelines. Guidelines for this support appear in the STDN Test and Simulation Support Plan, 530-NOP-STDN/TS.

### 2.7.5 Orbit Support Analysis

Prelaunch orbital error analyses are performed to determine the frequency with which user spacecraft state vectors are needed to achieve the orbital accuracies required by the user flight project.

## 2.8 Obtaining Ground Network Services

For all GN stations, flight projects should request GN support through NASA/GSFC, Code 451, Customer Commitment Office.

# Section 3. Norway Ground Station (SGS)

This section describes the EOS Polar Ground Station located in Svalbard, Norway, known as the Svalbard Ground Station (SGS).

The general characteristics of the station are as follows:

- Location: 78° 13′ 49″ N
  15° 23′ 34″ E
- One 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 3-1 is a photograph of the SGS antenna.
- Automatically scheduled by DSMC using WOTIS (see Section 9.3).
- Tracking services: 1- & 2-way Doppler and antenna autotracking angle.
- Baseband data interfaces: Internet Protocol (IP), serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 3.1 through 3.3 describe S- and X-band performance characteristics. Sections 3.4 and 3.5 describe the tracking services and baseband data interfaces, respectively.

**Figure 3-1. SGS Antenna**

## 3.1 S-Band Command

*Table 3-1* identifies the S-band command characteristics of the SGS.

## 3.2 S-Band Telemetry

*Table 3-2* identifies the S-band telemetry characteristics of the SGS.

**Table 3-1. SGS S-Band Command Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 2025 – 2120 MHz |
| EIRP | ≥ 66 dBWi |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 0.95° |
| Antenna Gain | 44.8 dBi |
| Output Power | 200 W |
| Carrier Modulation | PM, FM, or BPSK |
| Modulation Index | PM: 1.5 radians (peak)<br>FM: 50 kHz – 50 MHz deviation<br>BPSK: ±90° |
| Carrier Data Rate | ≤ 200 kbps |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 32 kbps |
| Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |

## 3.3 X-Band Telemetry

*Table 3-3* identifies the X-band telemetry characteristics of the SGS.

## 3.4 Tracking Services

### 3.4.1 Doppler Tracking

The SGS generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the SGS S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in *Table 3-4*.

**Table 3-2. SGS S-Band Telemetry Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2400 MHz |
| G/T | ≥ 23 dB/K |
| System Noise Temperature | 190 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 0.85° |
| Antenna Gain | 45.8 dBi |
| Carrier Modulation | PM, FM, BPSK, or AM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Carrier Data Rate | NRZ: 100 bps - 8 Mbps<br>Biϕ: 100 bps - 4 Mbps |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 1 Mbps |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi and/or Reed-Solomon (CCSDS) |

### 3.4.2 Antenna Autotracking Angle Data

The SGS can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as Universal Tracking Data Format (UTDF) messages. (See Table 4-1 of Reference [a] in Section 1.3, above.)

## 3.5 Baseband Data Interfaces

The SGS can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Sections 10.2, 10.3, and 10.4, respectively). SGS currently has a T-1 (1.544 Mbps) communications link and OC-1 (52 Mbps) communications link with GSFC to support command, telemetry, and ground station control and monitor. SGS will also mail high-rate, tape-recorded X-band telemetry data to the user as required (see Section 10.5).

**Table 3-3. SGS X-Band Telemetry Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 8000 – 9000 MHz |
| G/T (See Section 11 for detailed measurement data) | ≥ 35.4 dB/K with radome<br>(at 60° elevation) |
| System Noise Temperature | 150 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 0.23° |
| Antenna Gain | 57.6 dBi |
| Modulation | QPSK, SQPSK, UQPSK, or AQPSK |
| Data Rate | 6 – 150 Mbps |
| Data Format | NRZ-L or M |
| Decoding | Viterbi (R-½) and/or Reed-Solomon |

**Table 3-4. SGS Doppler Tracking Characteristics**

| Characteristic | Value |
|---|---|
| Counter Resolution | 0.001 cycles |
| Doppler Frequency Shift | ≤ 0.23 MHz |
| Doppler Bias Frequency | 0.24 MHz |
| Drift ($\Delta f/f$) | $4 \times 10^{-11}$ at 0.1 seconds |
| Accuracy | 0.01 Hz |
| Output Equation | $1000\ (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$ |

# Section 4. Wallops Flight Facility (WFF) Ground Stations

This section describes the GN stations located at WFF.

The primary orbital stations consist of the following ground stations:

- WGS (Section 4.1)
- LEO-T – WFF (Section 4.2)
- TOTS – WFF (Section 4.3)
- 9 meter (Section 4.4)

The other GN stations located at WFF are the following:

- MGTAS (Section 4.5)
- SATAN (Section 4.6)
- SCAMP (Section 4.7)
- METEOSAT (Section 4.8)
- Mobile Systems (Sections 4.9 – 4.13)
- UHF Command Systems (Section 4.14)
- Fixed And Mobile Radar Systems (Section 4.15)
- VHF Ground Stations (Section 4.16)

## 4.1 WGS

The general characteristics of the WGS ground station at WFF are as follows:

- Location: 37º 55′ 30″ N
  75º 28′ 35″ W
- One 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 4-1 is a photograph of the WGS antenna.
- Automatically scheduled by DSMC using WOTIS (see Section 9.3).
- Tracking services: 1- & 2-way Doppler and antenna autotracking angle.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 4.1.1 through 4.1.3 describe S-band and X-band performance characteristics. Sections 4.1.4 and 4.1.5 describe the tracking services and baseband data interfaces, respectively.

### 4.1.1 S-Band Command

*Table 4-1* identifies the S-band command characteristics of the WGS.

**Figure 4-1. WGS Antenna**

**Table 4-1. WGS S-Band Command Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 2025 – 2120 MHz |
| EIRP | ≥ 66 dBWi |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 0.95° |
| Antenna Gain | 44.8 dBi |
| Output Power | 200 W |
| Carrier Modulation | PM, FM, or BPSK |
| Modulation Index | PM: 1.5 radians (peak)<br>FM: 50 kHz – 50 MHz deviation<br>BPSK: ±90° |
| Carrier Data Rate | ≤ 200 kbps |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 32 kbps |
| Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |

### 4.1.2 S-Band Telemetry

*Table 4-2* identifies the S-band telemetry characteristics of the WGS.

**Table 4-2. WGS S-Band Telemetry Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2400 MHz |
| G/T | ≥ 23 dB/K |
| System Noise Temperature | 190 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 0.85° |
| Antenna Gain | 45.8 dBi |
| Carrier Modulation | PM, FM, BPSK, or AM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Carrier Data Rate | NRZ-L : 100 bps - 8 Mbps<br>Biϕ-L : 100 bps - 4 Mbps |
| Carrier Data Format | NRZ-L or Biϕ-L |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 1 Mbps |
| Subcarrier Data Format | NRZ-L or Biϕ-S |
| Decoding | Viterbi and/or Reed-Solomon (CCSDS) |

### 4.1.3 X-Band Telemetry

*Table 4-3* identifies the X-band telemetry characteristics of the WGS.

### 4.1.4 Tracking Services

#### 4.1.4.1 Doppler Tracking

WGS generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the WGS S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in *Table 4-4*.

**Table 4-3. WGS X-Band Telemetry Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 8000 – 9000 MHz |
| G/T | ≥ 35 dB/K |
| System Noise Temperature | 150 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 0.23° |
| Antenna Gain | 56.8 dBi |
| Modulation | QPSK or UQPSK |
| Data Rate | 6 – 110 Mbps |
| Data Format | NRZ-L or M |
| Decoding | Viterbi and/or Reed-Solomon (CCSDS) |

#### 4.1.4.2 Antenna Autotracking Angle Data

The WGS can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in Section 1.3, above.)

### 4.1.5 Baseband Data Interfaces

The WGS can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Sections 10.2, 10.3, and 10.4, respectively). WGS currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, low-rate telemetry, and ground station control and monitor.

WGS mails high-rate, tape-recorded X-band telemetry data to the user (see Section 10.5).

**Table 4-4. WGS Doppler Tracking Characteristics**

| Characteristic | Value |
|---|---|
| Counter Resolution | 0.001 cycles |
| Doppler Frequency Shift | ≤ 0.25 MHz |
| Doppler Bias Frequency | 0.24 MHz |
| Drift (Δf/f) | $4x10^{-11}$ at 0.1 seconds |
| Accuracy | 0.01 Hz |
| Output Equation | $1000\ (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$ |

## 4.2 LEO-T – WFF

The general characteristics of the LEO-T ground station at WFF are as follows:

- Location: 37º 55′ N<br>75º 28′ 25″ W
- One 5-meter antenna for simultaneously transmitting and receiving at S-band. Figure 4-2 is a photograph of the LEO-T antenna.
- Automatically scheduled by DSMC using WOTIS.
- Tracking services: None.
- Baseband data interfaces: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets.

Sections 4.2.1 and 4.2.2 describe S-band performance characteristics, and Section 4.2.3 describes the baseband data interfaces.

### 4.2.1 S-Band Command

5 identifies the S-band command characteristics of the LEO-T – WFF station.

### 4.2.2 S-Band Telemetry

*Table 4-6* identifies the S-band telemetry characteristics of the LEO-T – WFF station.

**Figure 4-2. LEO-T – WFF Antenna**

**Table 4-5. *LEO-T – WFF S-Band Command Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2025 – 2120 MHz |
| EIRP | ≥ 59.2 dBWi |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.8° |
| Antenna Gain | 38.6 dBi |
| Output Power | 200 W |
| Carrier Modulation | PM, BPSK, or FM |
| Modulation Index | PM: 0.2 - 1.5 radians (peak) |
| Carrier Data Rate | ≤ 200 kbps |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 32 kbps |
| Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |

**Table 4-6.** ***LEO-T – WFF S-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2300 MHz |
| G/T | ≥ 17 dB/K |
| System Noise Temperature | 174 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.83° |
| Antenna Gain | 39.4 dBi |
| Carrier Modulation | PM, FM, BPSK, or QPSK |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Carrier Data Rate | Uncoded: 8 Mbps<br>Rate-½ coded: 4 Mbps |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 4 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 1 Mbps |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi and/or Reed-Solomon (CCSDS) |

### 4.2.3 Baseband Data Interfaces

The LEO-T – WFF station can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Sections 10.2, 10.3, and 10.4, respectively). The station currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, low-rate telemetry, and ground station control and monitor.

## 4.3 TOTS – WFF

The general characteristics of the TOTS ground station at WFF are as follows:

- Location: 37º 55′ 11″ N
  75º 28′ 25″ W
- One 8-meter antenna for simultaneously transmitting and receiving at S-band. Figure 4-3 is a photograph of the TOTS antenna.
- Automatically scheduled by DSMC using WOTIS (see Section 9.3).
- Tracking services: 1- & 2-way Doppler and antenna autotracking angle.
- Baseband data interfaces: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets.

Sections 4.3.1 and 4.3.2 describe S-band performance characteristics. Sections 4.3.3 and 4.3.4 describe the tracking services and baseband data interfaces, respectively.

### 4.3.1 S-Band Command

Table 4-7 identifies the S-band command characteristics of the TOTS – WFF.

### 4.3.2 S-Band Telemetry

Table 4-8 identifies the S-band telemetry characteristics of the TOTS – WFF station.

**Figure 4-3. TOTS – WFF Antenna**

**Table 4-7.** ***TOTS – WFF S-Band Command Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2025 – 2120 MHz |
| EIRP | ≥ 62 dBWi |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.27° |
| Antenna Gain | 42.1 dBi |
| Output Power | 200 W |
| Carrier Modulation | PM, FM, or BPSK |
| Modulation Index | PM: 1.5 radians (peak)<br>FM: 50 kHz - 50 MHz deviation<br>BPSK: ±90° |
| Carrier Data Rate | ≤ 200 kbps |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 32 kbps |
| Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |

**Table 4-8.** ***TOTS – WFF S-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2400 MHz |
| G/T | ≥ 21 dB/K |
| System Noise Temperature | 150 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.14° |
| Antenna Gain | 42.8 dBi |
| Carrier Modulation | PM, BPSK, FM, or AM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Carrier Data Rate | Uncoded: 5 Mbps<br>Rate-½ coded: 2.5 Mbps |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 1 Mbps |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi and/or Reed-Solomon (CCSDS) |

### 4.3.3 Tracking Services

#### 4.3.3.1 Doppler Tracking

The TOTS – WFF station generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the TOTS – WFF S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 4-9.

#### 4.3.3.2 Antenna Autotracking Angle Data

TOTS – WFF can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in Section 1.3, above.)

**Table 4-9.** ***TOTS – WFF Doppler Tracking Characteristics***

| Characteristic | Value |
|---|---|
| Counter Resolution | 0.001 cycles |
| Doppler Frequency Shift | ≤ 0.25 MHz |
| Doppler Bias Frequency | 0.24 MHz |
| Drift (Δf/f) | $4 \times 10^{-11}$ at 0.1 seconds |
| Accuracy | 0.01 Hz |
| Output Equation | $1000\ (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$ |

### 4.3.4 Baseband Data Interfaces

The TOTS – WFF station can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Sections 10.2, 10.3, and 10.4, respectively). TOTS – WFF currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, low-rate telemetry, and ground station control and monitor.

## 4.4 9-Meter Ground Station

The general characteristics of the 9-m ground station at WFF are as follows:

- Location: 37º 55′ 38.5″ N
  75º 28′ 30″ W
- One 9-meter antenna for simultaneously transmitting at S-band while receiving at S-band. Figure 4-4 is a photograph of the 9-m ground station.
- Routine supports are automatically scheduled by DSMC using WOTIS (see Section 9.3).
- Real-time tracking services include: 1- & 2-way Doppler, Ranging, and antenna autotracking angles.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets.

Sections 4.4.1 and 4.4.2 describe S-band performance characteristics. Sections 4.4.3 and 4.4.4 describe the tracking services and baseband data interfaces, respectively.

**Figure 4-4.  9-m Antenna Ground Station**

### 4.4.1 S-Band Command

Table 4-10 identifies the S-band command characteristics of the 9-m ground station.

**Table 4-10.** ***9-m S-Band Command Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2025 – 2120 MHz |
| EIRP | 66 dBWi |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.12° |
| Antenna Gain | 43.1 dBi |
| Output Power | 200 W |
| Carrier Modulation | PM, FM, or BPSK |
| Modulation Index | PM: 3.0 radians (peak)<br>FM: 3 MHz<br>BPSK: ±90° |
| Carrier Data Rate | ≤ 5 Mbps |
| Subcarrier Frequency | 8 kHz, 16 kHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 2 kbps |
| Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |

### 4.4.2 S-Band Telemetry

Table 4-11 identifies the S-band telemetry characteristics of the 9-m ground station.

**Table 4-11.** ***9-m S-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2300 MHz |
| G/T | ≥ 24 dB/K |
| System Noise Temperature | 100 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.04° |
| Antenna Gain | 44.0 dBi |
| Carrier Modulation | PM, BPSK, FM, or AM |
| Modulation Index | PM: 0.2 – 1.4 radians (peak) |
| Carrier Data Rate | NRZ-L : = 15 Mbps<br>Biϕ-L : = 15 Mbps |
| Carrier Data Format | NRZ-L, M, or S; Biϕ-L, M, or S; DM-M or S; M2M, RZ, and PN Randomized |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 1 Mbps |
| Subcarrier Data Format | NRZ-L, M, or S; Biϕ-L, M, or S; DM-M or S; M2M, RZ, and PN Randomized |
| Decoding | Viterbi and/or Reed-Solomon (CCSDS) |

### 4.4.3 Tracking Services

#### 4.4.3.1 Doppler Tracking

The 9-m ground station generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the 9-m S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in Table 4-12.

#### 4.4.3.2 Range Tracking

Range tracking characteristics are shown in Table 4-13.

#### 4.4.3.3 Antenna Autotracking Angle Data

The 9-m ground station can record the angle of the ground antenna as it autotracks the user. This data is provided to the Flight Dynamics Facility as UTDF messages.

### 4.4.4 Baseband Data Interfaces

The 9-m ground station can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets.

**Table 4-12.** ***9-m Doppler Tracking Characteristics***

| Characteristic | Value |
|---|---|
| Counter Resolution | 0.001 cycles |
| Doppler Frequency Shift | ≤ 0.25 MHz |
| Doppler Bias Frequency | 0.24 MHz |
| Drift (Δf/f) | $4x10^{-11}$ at 0.1 seconds |
| Accuracy | 0.01 Hz |
| Output Equation | $1000\ (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$ |

**Table 4-13. *9-m Range Tracking Characteristics***

| Characteristic | Value |
|---|---|
| Operating Modes | 2-way coherent and non-coherent |
| Modulation Index | Carrier: 0.2 – 1.5 radians (peak)<br>Subcarrier (1.7 MHz): 0.3 – 1.2 radians (peak) |
| Major Tone Frequencies | 500 kHz, 100 kHz, and 20 kHz |
| Minor Tone Frequencies | 100 kHz, 20 kHz, and 4 kHz on carrier or 1.7-MHz subcarrier<br>800 Hz, 160 Hz, 40 Hz, and 10 Hz on 4-kHz tone |
| $C_{received}/N$ | ≥ 10 dB |
| Tone Power/$N_0$ | > 15 dB-Hz |
| Accuracy | 1.0 m |
| Unambiguous Range | ≤ 644,000 km |

## 4.5 MGTAS

The general characteristics of the MGTAS ground station at WFF are as follows:

- Location: 37º 55′ N<br>75º 28′ W
- Two 7.3-meter L- and S-band receive-only antennas. Figure 4-5 is a photograph of the MGTAS antennas.
- Automatically scheduled by DSMC using WOTIS.
- Tracking services: 1-way Doppler, ranging, and antenna autotracking angle.
- Baseband data interfaces: IP and 4800-bit blocks encapsulated in IP packets.

Sections 4.5.1 through 4.5.3 describe the L- and S-band receive-only performance characteristics. Sections 4.5.4 and 4.5.5 describe the tracking services and baseband data interfaces, respectively.

### 4.5.1 L1-Band Telemetry

*Table 4-14* identifies the L1-band telemetry characteristics of the MGTAS station (the two L1-band systems are functionally identical).

**Figure 4-5. MGTAS Antennas**

**Table 4-14.** ***MGTAS L1-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 1435 – 1535 MHz |
| G/T | ≥ 11.0 dB/K |
| System Noise Temperature | 446 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.69° |
| Antenna Gain | 37.5 dBi |
| Carrier Modulation | PM, FM, or AM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Carrier Data Rate | ≤ 6.6 Mbps |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) and/or Reed-Solomon (CCSDS) |

### 4.5.2 L2-Band Telemetry

*Table 4-15* identifies the L2-band telemetry characteristics of MGTAS (the two L2-Band systems are functionally identical).

### 4.5.3 S-Band Telemetry

*Table 4-16* identifies the S-band telemetry characteristics of MGTAS (the two S-Band systems are functionally identical).

### 4.5.4 Tracking Services

#### 4.5.4.1 Doppler Tracking

MGTAS generates 1-way Doppler tracking data derived from the S-band downlink carrier. Doppler tracking characteristics are shown in *Table 4-17*.

#### 4.5.4.2 Range Tracking

Range tracking characteristics are shown in *Table 4-18*.

#### 4.5.4.3 Antenna Autotracking Angle Data

MGTAS can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in Section 1.3, above.)

### 4.5.5 Baseband Data Interfaces

The MGTAS station can send and receive baseband data in either of the following formats: IP and 4800-bit blocks encapsulated in IP packets (see Sections 10.2 and 10.4, respectively). MGTAS currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, low-rate telemetry, and ground station control and monitor.

**Table 4-15.** ***MGTAS L2-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 1670 – 1720 MHz |
| G/T | ≥ 12.5 dB/K |
| System Noise Temperature | 510 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.69° |
| Antenna Gain | 39.6 dBi |
| Carrier Modulation | PM, AM, or FM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Carrier Data Rate | ≤ 6.6 Mbps |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) and/or Reed-Solomon (CCSDS) |

**Table 4-16.** ***MGTAS S-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2400 MHz |
| G/T | ≥ 15.5 dB/K |
| System Noise Temperature | 446 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.28° |
| Antenna Gain | 42.0 dBi |
| Carrier Modulation | PM, AM, or FM |
| Modulation Index | PM:  0.2 – 2.8 radians (peak) |
| Carrier Data Rate | ≤ 6.6 Mbps |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) and/or Reed-Solomon (CCSDS) |

**Table 4-17.** ***MGTAS Doppler Tracking Characteristics***

| Characteristic | Value |
|---|---|
| Counter Resolution | 0.001 cycles |
| Doppler Frequency Shift | ≤ 0.25 MHz |
| Doppler Bias Frequency | 0.24 MHz |
| Drift ($\Delta f/f$) | $4 \times 10^{-11}$ at 0.1 seconds |
| Output Equation | $1000 (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$ |

**Table 4-18. *MGTAS Range Tracking Characteristics***

| Characteristic | Value |
|---|---|
| Operating Modes | 2-way coherent and non-coherent |
| Modulation Index | Carrier: 0.2 – 1.5 radians (peak)<br>Subcarrier (1.7 MHz): 0.3 – 1.2 radians (peak) |
| Major Tone Frequencies | 500 kHz, 100 kHz, and 20 kHz |
| Minor Tone Frequencies | 100 kHz, 20 kHz, and 4 kHz on carrier or 1.7-MHz subcarrier<br>800 Hz, 160 Hz, 40 Hz, and 10 Hz on 4-kHz tone |
| $C_{received}/N$ | ≥ 10 dB |
| Tone Power/$N_0$ | > 15 dB-Hz |
| Accuracy | 1.0 m |
| Unambiguous Range | ≤ 644,000 km |

## 4.6 SATAN

The general characteristics of the SATAN ground station at WFF are as follows:

- Location: 37° 55′ N
  75° 28′ W
- One transmit array and two receive array antennas for simultaneously transmitting and receiving at VHF. Figure 4-6 is a photograph of the SATAN antennas.
- Manually scheduled by DSMC.
- Tracking service: Ranging.
- Baseband data interfaces: IP and 4800-bit blocks encapsulated in IP packets.

Sections 4.6.1 and 4.6.2 describe VHF performance characteristics. Sections 4.6.3 and 4.6.4 describe the tracking services and baseband data interfaces, respectively.

### 4.6.1 VHF Command

*Table 4-19* identifies the VHF command characteristics of the SATAN station.

### 4.6.2 VHF Telemetry

*Table 4-20* identifies the VHF telemetry characteristics of the SATAN station.

**Figure 4-6.  SATAN Antennas**

**Table 4-19.** ***SATAN VHF Command Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 147 – 155 MHz |
| EIRP | ≥ 59 dBWi |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 13° |
| Antenna Gain | 19 dBi |
| Output Power | 10 kW |
| Carrier Modulation | PM, FM, or AM |
| Modulation Index | PM: 3 radians (peak)<br>FM: 1 MHz deviation |
| Carrier Data Rate | 100 bps – 20 kbps |
| Subcarrier Frequency | 8 kHz or 16 kHz |
| Subcarrier Modulation | FSK or PSK |
| Subcarrier Data Rate | 1 kbps – 2 kbps |
| Data Format | NRZ-L or Biϕ-L |

**Table 4-20.** ***SATAN VHF Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 136 – 138 MHz |
| G/T | ≥ -7.03 dB/K |
| System Noise Temperature | 800 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 12.5° |
| Antenna Gain | 22 dBi |
| Carrier Modulation | PM, FM, or AM |
| Modulation Index | PM: 0.2 – 1.4 radians (peak) |
| Carrier Data Rate | ≤ 10 Mbps |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½ or Rate-1/3) and/or Reed-Solomon (CCSDS) |

### 4.6.3 Tracking Services

SATAN supports only range tracking service.

#### 4.6.3.1 Range Tracking

Range tracking characteristics are shown in *Table 4-21*.

### 4.6.4 Baseband Data Interfaces

The SATAN station can send and receive baseband data in either of the following formats: IP and 4800-bit blocks encapsulated in IP packets (see Sections 10.2 and 10.4, respectively). MGTAS currently has a T-1 (1.544 Mbps) communications link with GSFC to support low-rate telemetry.

**Table 4-21.** ***SATAN Range Tracking Characteristics***

| Characteristic | Value |
|---|---|
| Operating Mode | 2-way coherent |
| PM Modulation Index | 0.2 – 1.5 radians (peak) on carrier/715-kHz subcarrier |
| Minor Tone Frequencies | 4 kHz on carrier<br>800 Hz, 160 Hz, 40 Hz, and 10 Hz on 4-kHz tone |
| $C_{received}/N$ | ≥ 15 dB |

The user does not send command data directly to SATAN. Instead, SATAN maintains a database of user commands. Using telephone or e-mail, a user requests specific commands from the database, which SATAN then transmits to the user.

## 4.7 SCAMP

The general characteristics of the SCAMP ground station at WFF are as follows:

- Location: 37° 55′ N
  75° 28′ W
- One VHF transmit-only antenna array. Figure 4-7 is a photograph of the SCAMP antenna.
- Manually scheduled by DSMC.
- Tracking services: Ranging (with SATAN receive system).
- Baseband data interface: None (uses a command database).

Section 4.6.1 describes the VHF transmit-only performance characteristics. Sections 4.6.2 and 4.6.3 describe the tracking services and baseband data interface, respectively.

### 4.7.1 VHF Command

*Table 4-22* identifies the VHF command characteristics of the SCAMP station.

### 4.7.2 Tracking Services

SCAMP supports range tracking only when used with the receive portion of the SATAN station.

#### 4.7.2.1 Range Tracking

Range tracking characteristics are shown in *Table 4-23*.

**Figure 4-7. SCAMP Antenna**

**Table 4-22. *SCAMP VHF Command Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 147 – 155 MHz |
| EIRP | ≥ 57 dBWi |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 20° |
| Antenna Gain | 17 dBi |
| Output Power | 10 kW |
| Carrier Modulation | PM, FM, or AM |
| Modulation Index | PM: 3 radians (peak)<br>FM: 1 MHz deviation |
| Carrier Data Rate | 100 bps – 20 kbps |
| Subcarrier Frequency | 8 kHz or 16 kHz |
| Subcarrier Modulation | FSK or PSK |
| Subcarrier Data Rate | 1 kbps – 2 kbps |
| Data Format | NRZ-L or Biϕ-L |

**Table 4-23. *SCAMP Range Tracking Characteristics***

| Characteristic | Value |
|---|---|
| Operating Mode | Coherent (when operating with *SATAN* receiver) |
| PM Modulation Index | 0.2 – 1.5 radians (peak) on carrier |
| Major Tone Frequency | 20 kHz |

### 4.7.3 Baseband Data Interfaces

SCAMP is a transmit-only station, but the user does not send command data directly to the station. Instead, SCAMP maintains a database of user commands. Using telephone or e-mail, a user requests specific commands from the database, which SCAMP then transmits to the user.

## 4.8 METEOSAT

The general characteristics of the METEOSAT ground station at WFF are as follows:

- Location: 37° 55′ N
  75° 28′ W
- One 7.3-meter L-band receive-only antenna. Figure 4-8 is a photograph of the METEOSAT antenna.
- Manually scheduled by DSMC.
- Tracking services: None.
- Baseband data interface: None (data is sent via telephone).

Section 4.8.1 describes the L-band receive-only performance characteristics, and Section 4.8.2 describes the baseband data interface.

### 4.8.1 L-Band Telemetry

*Table 4-24* identifies the L-band telemetry characteristics of the METEOSAT station.

### 4.8.2 Baseband Data Interfaces

METEOSAT records received baseband data on computer disk. The recorded data is sent via commercial telephone lines. METEOSAT does not use the NASCOM or NASA Integrated Services Network (NISN) data circuits described in section 10.

**Figure 4-8. METEOSAT Antenna**

**Table 4-24.** ***METEOSAT L-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 1685 – 1710 MHz |
| G/T | ≥ 12 dB/K |
| System Noise Temperature | 500 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.7° |
| Antenna Gain | 39 dBi |
| Carrier Modulation | PM, FM, or AM |
| Modulation Index | PM: 0.2 – 1.4 radians (peak) |
| Carrier Data Rate | ≤ 6.6 Mbps |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½ or Rate-1/3) and/or Reed-Solomon (CCSDS) |

## 4.9 18 Foot Mobile System

The general characteristics of the WFF 18 Foot Mobile System are as follows:

- Location: Varies
- One 5.5-meter L- and S-band receive-only antenna. Figure 4-9 is a photograph of the 18 Foot antenna.
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking Services: Antenna autotracking angle.
- Baseband data interface: Tape.

Sections 4.9.1, 4.9.2, and 4.9.3 describe L-band and S-band performance characteristics. Sections 4.9.4 and 4.9.5 describe the tracking services and baseband data interfaces, respectively.

### 4.9.1 L1-Band Telemetry

*Table 4-25* identifies the L1-band telemetry characteristics of the 18 Foot Mobile System.

### 4.9.2 L2-Band Telemetry

*Table 4-26* identifies the L2-band telemetry characteristics of the 18 Foot Mobile System.

### 4.9.3 S-Band Telemetry

*Table 4-27* identifies the S-band telemetry characteristics of the 18 Foot Mobile System.

### 4.9.4 Tracking Services

#### 4.9.4.1 Antenna Autotracking Angle Data

The 18 Foot Mobile System can record the angle of its ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in section 1.3, above.)

### 4.9.5 Baseband Data Interfaces

The 18 Foot Mobile System has no IP or point-to-point data line interfaces with NISN. The station tape records telemetry data and mails it to the user (see Section 10.5).

**Figure 4-9.  18 Foot Mobile System Antenna**

**Table 4-25.** ***18 Foot Mobile System L1-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 1435 – 1535 MHz |
| G/T | ≥ 9.4 dB/K (at 45° elevation angle) |
| System Noise Temperature | 350 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 2.25° |
| Antenna Gain | 34.9 dBi (at 45° elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM:  0.2 – 1.4 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) and/or Reed-Solomon (CCSDS) |

**Table 4-26.** ***18 Foot Mobile System L2-Band Telemetry Characteristics***

| Characteristic | Value |
| --- | --- |
| Frequency | 1615 – 1720 MHz |
| G/T | ≥ 11.6 dB/K (at 45º elevation angle) |
| System Noise Temperature | 350 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 2.25° |
| Antenna Gain | 37.1 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM: 0.2 – 1.4 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) and/or Reed-Solomon (CCSDS) |

**Table 4-27.** ***18 Foot Mobile System S-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2300 MHz |
| G/T | ≥ 14.6 dB/K (at 45º elevation angle) |
| System Noise Temperature | 310 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.7° |
| Antenna Gain | 39.5 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM: 0.2 – 1.4 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) |

## 4.10 20 Foot Mobile System

The general characteristics of the WFF 20 Foot Mobile System are as follows:

- Location: Varies
- One 6.1-meter L- and S-band receive-only antenna. Figure 4-10 is a photograph of the 20 Foot antenna.
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking Services: Antenna autotracking angle.
- Baseband data interface: Tape.

Sections 4.10.1, 4.10.2, and 4.10.3 describe L-band and S-band performance characteristics. Sections 4.10.4 and 4.10.5 describe the tracking services and baseband data interfaces, respectively.

### 4.10.1 L1-Band Telemetry

*Table 4-28* identifies the L1-band telemetry characteristics of the 20 Foot Mobile System.

### 4.10.2 L2-Band Telemetry

*Table 4-29* identifies the L2-band telemetry characteristics of the 20 Foot Mobile System.

### 4.10.3 S-Band Telemetry

*Table 4-30* identifies the S-band telemetry characteristics of the 20 Foot Mobile System.

### 4.10.4 Tracking Services

#### 4.10.4.1 Antenna Autotracking Angle Data

The 20 Foot Mobile System can record the angle of its ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in section 1.3, above.)

### 4.10.5 Baseband Data Interfaces

The 20 Foot Mobile System has no IP or point-to-point data line interfaces with NISN. The station tape records telemetry data and mails it to the user (see Section 10.5).

**Figure 4-10. 20 Foot Mobile System Antenna**

**Table 4-28. *20 Foot Mobile System L1-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 1435 – 1535 MHz |
| G/T | ≥ 10.3 dB/K (at 45º elevation angle) |
| System Noise Temperature | 350 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 2.03° |
| Antenna Gain | 35.8 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) |

**Table 4-29.** ***20 Foot Mobile System L2-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 1615 – 1720 MHz |
| G/T | ≥ 12.5 dB/K (at 45º elevation angle) |
| System Noise Temperature | 350 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 2.03° |
| Antenna Gain | 38.0 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) |

**Table 4-30.** ***20 Foot Mobile System S-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2400 MHz |
| G/T | ≥ 15.5 dB/K (at 45º elevation angle) |
| System Noise Temperature | 316 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.53° |
| Antenna Gain | 40.5 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM:  0.2 – 2.8 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) |

## 4.11 10 Foot Mobile System

The general characteristics of the WFF 10 Foot Mobile System are as follows:

- Location: Varies
- One 3.0-meter L- and S-band receive-only antenna. Figure 4-11 is a photograph of the 10 Foot antenna.
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking Services: Antenna autotracking angle.
- Baseband data interface: Tape.

Sections 4.11.1, 4.11.2, and 4.11.3 describe L-band and S-band performance characteristics. Sections 4.11.4 and 4.11.5 describe the tracking services and baseband data interfaces, respectively.

### 4.11.1 L1-Band Telemetry

*Table 4-31* identifies the L1-band telemetry characteristics of the 10 Foot Mobile System.

### 4.11.2 L2-Band Telemetry

*Table 4-32* identifies the L2-band telemetry characteristics of the 10 Foot Mobile System.

### 4.11.3 S-Band Telemetry

*Table 4-33* identifies the S-band telemetry characteristics of the 10 Foot Mobile System.

### 4.11.4 Tracking Services

#### 4.11.4.1 Antenna Autotracking Angle Data

The 10 Foot Mobile System can record the angle of its ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in section 1.3, above.)

### 4.11.5 Baseband Data Interfaces

The 10 Foot Mobile System has no IP or point-to-point data line interfaces with NISN. The station tape records telemetry data and mails it to the user (see Section 10.5).

**Figure 4-11.  10 Foot Mobile System Antenna**

**Table 4-31***.  10 Foot Mobile System L1-Band Telemetry Characteristics*

| Characteristic | Value |
|---|---|
| Frequency | 1435 – 1535 MHz |
| G/T | ≥ 4.1 (at 45º elevation angle) |
| System Noise Temperature | 435 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 4.5° |
| Antenna Gain | 30.5 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM:  0.2 – 2.8 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) |

**Table 4-32.** ***10 Foot Mobile System L2-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 1615 – 1720 MHz |
| G/T | ≥ 5.1 (at 45º elevation angle) |
| System Noise Temperature | 435 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 4.1° |
| Antenna Gain | 31.5 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) |

**Table 4-33.** ***10 Foot Mobile System S-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2300 MHz |
| G/T | ≥ 8.0 dB/K (at 45º elevation angle) |
| System Noise Temperature | 435 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 3.1° |
| Antenna Gain | 34.4 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM:  0.2 – 2.8 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) |

## 4.12 8 Foot Mobile System

The general characteristics of the WFF 8 Foot Mobile System are as follows:

- Location: Varies
- One 2.4-meter L- and S-band receive-only antenna. Figure 4-12 is a photograph of the 8 Foot antenna.
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking Services: Antenna autotracking angle.
- Baseband data interface: Tape.
- Sections 4.12.1, 4.12.2, and 4.12.3 describe L-band and S-band performance characteristics. Sections 4.12.4 and 4.12.5 describe the tracking services and baseband data interfaces, respectively.

### 4.12.1 L1-Band Telemetry

*Table 4-34* identifies the L1-band telemetry characteristics of the 8 Foot Mobile System.

### 4.12.2 L2-Band Telemetry

*Table 4-35* identifies the L2-band telemetry characteristics of the 8 Foot Mobile System.

### 4.12.3 S-Band Telemetry

*Table 4-36* identifies the S-band telemetry characteristics of the 8 Foot Mobile System.

### 4.12.4 Tracking Services

#### 4.12.4.1 Antenna Autotracking Angle Data

The 8 Foot Mobile System can record the angle of its ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in section 1.3, above.)

### 4.12.5 Baseband Data Interfaces

The 8 Foot Mobile System has no IP or point-to-point data line interfaces with NISN. The station tape records telemetry data and mails it to the user (see Section 10.5).

**Figure 4-12. 8 Foot Mobile System Antenna**

**Table 4-34.** ***8 Foot Mobile System L1-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 1435 – 1535 MHz |
| G/T | ≥ 3.3 dB/K (at 45º elevation angle) |
| System Noise Temperature | 350 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 5.1° |
| Antenna Gain | 28.8 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) |

**Table 4-35.** ***8 Foot Mobile System L2-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 1615 – 1720 MHz |
| G/T | ≥ 4.5 dB/K (at 45º elevation angle) |
| System Noise Temperature | 350 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 5.1° |
| Antenna Gain | 30.0 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) |

**Table 4-36. *8 Foot Mobile System S-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2300 MHz |
| G/T | ≥ 7.0 dB/K (at 45º elevation angle) |
| System Noise Temperature | 350 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 3.9° |
| Antenna Gain | 32.5 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM:  0.2 – 2.8 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) |

## 4.13 23 Foot Mobile System

The general characteristics of the WFF 23 Foot Mobile System are as follows:

- Location: Varies
- One 7.0-meter L- and S-band receive-only antenna. Figure 4-13 is a photograph of the 23 Foot antenna.
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking Services: Antenna autotracking angle.
- Baseband data interface: Tape.
- Sections 4.13.1, 4.13.2, and 4.13.3 describe L-band and S-band performance characteristics. Sections 4.13.4 and 4.13.5 describe the tracking services and baseband data interfaces, respectively.

### 4.13.1 L1-Band Telemetry

*Table 4-37* identifies the L1-band telemetry characteristics of the 23 Foot Mobile System.

### 4.13.2 L2-Band Telemetry

*Table 4-38* identifies the L2-band telemetry characteristics of the 23 Foot Mobile System.

### 4.13.3 S-Band Telemetry

*Table 4-39* identifies the S-band telemetry characteristics of the 23 Foot Mobile System.

### 4.13.4 Tracking Services

#### 4.13.4.1 Antenna Autotracking Angle Data

The 23 Foot Mobile System can record the angle of its ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in section 1.3, above.)

### 4.13.5 Baseband Data Interfaces

The 23 Foot Mobile System has no IP or point-to-point data line interfaces with NISN. The station tape records telemetry data and mails it to the user (see Section 10.5).

**Figure 4-13.  23 Foot Mobile System Antenna**

**Table 4-37.** ***23 Foot Mobile System L1-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 1435 – 1535 MHz |
| G/T | ≥ 12.0 dB/K (at 45º elevation angle) |
| System Noise Temperature | 398 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.97° |
| Antenna Gain | 38 (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM:  0.2 – 2.8 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) |

**Table 4-38.** ***23 Foot Mobile System L2-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 1615 – 1720 MHz |
| G/T | ≥ 13.7 dB/K (at 45º elevation angle) |
| System Noise Temperature | 240 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.70° |
| Antenna Gain | 37.5 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) and/or Reed-Solomon (CCSDS) |

**Table 4-39.** ***23 Foot Mobile System S-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2400 MHz |
| G/T | ≥ 20.0 dB/K (at 45º elevation angle) |
| System Noise Temperature | 153 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.38° |
| Antenna Gain | 40.55 dBi (at 45º elevation angle) |
| Carrier Modulation | BPSK, PM, AM, or FM |
| Modulation Index | PM:  0.2 – 2.8 radians (peak) |
| Main Carrier Data Rate | ≤ 4.0 Mbps |
| Main Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Ratio of Subcarrier Frequency to Subcarrier Data Rate | > 1.5 |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi (Rate-½) and/or Reed-Solomon (CCSDS) |

## 4.14 UHF Command Systems

This section describes UHF Command Systems located at WFF:

- Fixed UHF Command System (Section 4.13.1)
- Mobile UHF Command Systems (Section 4.13.2)

### 4.14.1 Fixed UHF Command System

The general characteristics of the Fixed UHF Command System at WFF are as follows:

- Location: 37° 51′ 59″ N<br>75° 30′ 18″ W
- Two Orbit quad-helix UHF transmit-only antennas. Figure 4-14 is a photograph of the Fixed UHF Command System antennas.
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking Services: None
- Baseband command interfaces: Refer to 4.13.1.2

Section 4.14.1.1 describes the command characteristics of the Fixed UHF Command System.

Section 4.14.1.2 describes the baseband command interfaces.

**Figure 4-14. Fixed UHF Command System Antennas**

#### 4.14.1.1 UHF Command

*Table 4-40 i*dentifies the command characteristics of the Fixed UHF Command System.

#### 4.14.1.2 Baseband Command Interfaces

The fixed command system located at WFF is remotely controlled from the WFF Range Safety Officer (RSO) console at the WFF Range Control Center (RCC) via a Time Division Multiple Access (TDMA) system. The TDMA consist of encoders near the RSO console and decoders near the UHF command transmitters area. These encoders and decoders are connected with twisted pair communication lines.

**Table 4-40. Fixed UHF Command System Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 410 – 450 MHz |
| EIRP | ≥ 76 dBm |
| Polarization | LHC |
| Antenna Beamwidth | 20° |
| Antenna Gain | 18 dB |
| Output Power | 1000 W |
| Carrier Modulation | FM<br>IRIG Standard Tones (1-20) |

### 4.14.2 Mobile UHF Command System

The general characteristics of the Mobile UHF Command System at WFF are as follows:

- Location: Varies
- Two Taco single-helix UHF transmit-only antennas. Figure 4-15 is a photograph of the Mobile UHF Command System antennas
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking Services: None
- Baseband command interfaces: Refer to 4.14.2.2

Section 4.14.2.1 describes the command characteristics of the Mobile UHF Command System. Section 4.14.2.2 describes the baseband command interfaces.

**Figure 4-15. Mobile UHF Command System Antennas**

#### 4.14.2.1 UHF Command

*Table 4-41* identifies the command characteristics of the Mobile UHF Command System.

#### 4.14.2.2 Baseband Command Interfaces

These systems can be standalone or remotely controlled. In the standalone mode a Range Safety representative has to initiate the command locally. In the remotely controlled mode the command system receives commands from the Range Safety Officer (RSO) console at the WFF RCC or from another mobile command system. The Mobile UHF Command system receives the commands via a Time Division Multiple Access (TDMA) system. The TDMA consist of encoders near the RSO console or in the additional mobile command system and decoders in the mobile command transmitters area. These encoders and decoders are connected with modems and standard telephone communications lines.

**Table 4-41.** ***Mobile UHF Command System Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 410 – 450 MHz |
| EIRP | ≥ 73 dBm |
| Polarization | LHC |
| Antenna Beamwidth | 27 degrees |
| Antenna Gain | 15 dB |
| Output Power | 1000 W |
| Carrier Modulation | FM<br>IRIG Standard Tones (1-20) |

## 4.15 Fixed And Mobile Radar Systems

This section describes the seven fixed radar systems and the four mobile radar systems located at WFF:

- Fixed ASRF Radar System (Section 4.15.1)
- Fixed Spandar Radar System (Section 4.15.2)
- Fixed AN/ASR-7 Radar System (Section 4.15.3)
- Fixed Marine Pathfinder Radar System (Section 4.15.4)
- Fixed Radar #3 Radar System (Section 4.15.5)
- Fixed Radar #5 Radar System (Section 4.15.6)
- Fixed Radar #18 Radar System (Section 4.15.7)
- Mobile Radar #2 Radar System (Section 4.15.8)
- Mobile Radar #8 Radar System (Section 4.15.9)
- Mobile Radar #10 Radar System (Section 4.15.10)
- Mobile Radar #11 Radar System (Section 4.15.11)

### 4.15.1 Fixed ASRF Radar System

The general characteristics of the ASRF Radar System at WFF are as follows:

- Location: 37° 51′ 20″ N
  75° 30′ 44″ W
- One 18.3-meter RADAR antenna
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking services: RADAR
- Data Processing: Data processed into photos, graphs, and/or text.

Section 4.15.1.1 describes the tracking services.

#### 4.15.1.1 Tracking Services

*Table 4-42* identifies the ASRF Radar System characteristics.

### 4.15.2 Fixed Spandar Radar System

The general characteristics of the Spandar Radar System at WFF are as follows:

- Location: 37° 51′ 17″ N
  75° 30′ 47″ W
- One 18.3-meter RADAR antenna
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking services: RADAR
- Data Processing: Data processed into photos, graphs, and/or text.

Section 4.15.2.1 describes the tracking services.

#### 4.15.2.1 Tracking Services

*Table 4-43* identifies the Spandar Radar System characteristics.

**Table 4-42.** ***ASRF Radar Characteristics***

| Characteristic | Value |
|---|---|
| Wave Length Band | (UHF-band) |
| Peak Power Output | 8 MW |
| Pulse Rate Frequency | 320 – 960 pps |
| Beamwidth | 2.9° |
| Antenna Size | 18.29 m |
| Antenna Gain | 36 dB |
| Maximum Range | 800 nm |
| 1-$m^2$ Skin Track | 1480 km |
| Range Precision | 204 yards |
| Angle Precision | 2.0 Mils |
| Slew Rate | AZ: 8 deg/sec<br>EL: 8 deg/sec |

**Table 4-43.** ***Spandar Radar Characteristics***

| Characteristic | Value |
|---|---|
| Wave Length Band | (S-band) |
| Peak Power Output | 5 MW |
| Pulse Rate Frequency | 160, 310, 640, 960 pps |
| Beamwidth | 0.39° |
| Antenna Size | 18.29 m |
| Antenna Gain | 52.8 dB |
| Maximum Range | 480,000 km |
| 1-$m^2$ Skin Track | 2200 km |
| Range Precision | 5 m |
| Angle Precision | 1.0 Mils |
| Slew Rate | AZ: 15 deg/sec<br>EL: 15 deg/sec |

### 4.15.3 Fixed AN/ASR-7 Radar System

The general characteristics of the AN/ASR-7 Radar System at WFF are as follows:

- Location: 37° 55′ 58″ N
  75° 28′ 19″ W
- One 5.33×2.74-meter RADAR antenna
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking services: RADAR
- Data Processing: Real-time data for WFF Range Safety only.

Section 4.14.3.1 describes the tracking services.

#### 4.15.3.1 Tracking Services

*Table 4-44* identifies the AN/ASR-7 Radar System characteristics.

### 4.15.4 Fixed Marine Pathfinder Radar System

The general characteristics of the Marine Pathfinder Radar System at WFF are as follows:

- Location: 37° 50′ 27″ N
  75° 28′ 51″ W
- One 3.67×0.15-meter RADAR antenna
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking services: RADAR
- Data Processing: Real-time data for WFF Range Safety only.

Section 4.15.4.1 describes the tracking services.

#### 4.15.4.1 Tracking Services

*Table 4-45* identifies the Marine Pathfinder Radar System characteristics.

**Table 4-44.** ***AN/ASR-7 Radar Characteristics***

| Characteristic | Value |
|---|---|
| Wave Length Band | (S-band) |
| Peak Power Output | 425 kW |
| Pulse Rate Frequency | 713, 1200, others pps |
| Beamwidth | 1.5 degrees |
| Antenna Size | 5.33×2.74 m |
| Antenna Gain | 34 dB |
| Maximum Range | 110 km |
| 1-$m^2$ Skin Track | 75 (A/C) km |
| Range Precision | ±1% |
| Angle Precision | 2 ¼ degrees |
| Slew Rate | N/A |

**Table 4-45.** ***Marine Pathfinder Radar Characteristics***

| Characteristic | Value |
|---|---|
| Wave Length Band | (X-band) |
| Peak Power Output | 20 kW |
| Pulse Rate Frequency | 900, 1800, 3600 pps |
| Beamwidth | 0.9 degrees |
| Antenna Size | 3.67×0.15 m |
| Antenna Gain | 32 dB |
| Maximum Range | 125 km |
| 1-$m^2$ Skin Track | 8 nm |
| Range Precision | 0.3% or 4 yards whichever is greater |
| Angle Precision | 0.3 degrees |
| Slew Rate | AZ: 20 RPM<br>EL: N/A |

### 4.15.5 Fixed RADAR #3 Radar System

The general characteristics of the Fixed RADAR #3 – RIR-716 Radar System at WFF are as follows:

- Location: 37° 50′ 29″ N
  75° 29′ 06″ W
- One 3.66-meter RADAR antenna
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking services: RADAR
- Data Processing: Hardcopy plots of tracking versus time.

Sections 4.15.5.1 and 4.15.5.2 describe the tracking services and baseband data interfaces, respectively.

#### 4.15.5.1 Tracking Services

*Table 4-46* identifies the RADAR #3 Radar System characteristics.

#### 4.15.5.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

### 4.15.6 Fixed RADAR #5 Radar System

The general characteristics of the Fixed RADAR #5 – RIR-706 Radar System at WFF are as follows:

- Location: 37° 51′ 37″ N
  75° 30′ 33″ W
- One 8.84-meter RADAR antenna
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking services: RADAR
- Data Processing: Hardcopy plots of tracking versus time.

Sections 4.15.6.1 and 4.15.6.2 describe the tracking services and baseband data interfaces, respectively.

#### 4.15.6.1 Tracking Services

*Table 4-47* identifies the RADAR #5 Radar System characteristics.

**Table 4-46.** ***RADAR #3 Radar Characteristics***

| Characteristic | Value |
|---|---|
| Wave Length Band | (C-band) |
| Peak Power Output | 1 MW |
| Pulse Rate Frequency | 160, 320, 640 pps |
| Beamwidth | 1.23° |
| Antenna Size | 3.66 m |
| Antenna Gain | 43 dB |
| Maximum Range | 60,000 km |
| 1-$m^2$ Skin Track | 350 km |
| Range Precision | 10 m |
| Angle Precision | 0.2 Mils |
| Slew Rate | AZ: 30 deg/sec<br>EL: 30 deg/sec |

**Table 4-47.** ***RADAR #5 Radar Characteristics***

| Characteristic | Value |
|---|---|
| Wave Length Band | (C-band) |
| Peak Power Output | 3 MW |
| Pulse Rate Frequency | 160, 320, 640 pps |
| Beamwidth | 0.39° |
| Antenna Size | 8.84 m |
| Antenna Gain | 51 dB |
| Maximum Range | 60,000 km |
| 1-$m^2$ Skin Track | 1300 km |

| | |
|---|---|
| Range Precision | 10 m |
| Angle Precision | 0.1 Mils |
| Slew Rate | AZ: 20 deg/sec<br>EL: 20 deg/sec |

#### 4.15.6.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

### 4.15.7 Fixed RADAR #18 Radar System

The general characteristics of the Fixed RADAR #18 – RIR-778C Radar System at WFF are as follows:

- Location: 37° 56′ 39″ N
  75° 27′ 51″ W
- One 4.88-meter RADAR antenna
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking services: RADAR
- Data Processing: Hardcopy plots of tracking versus time.

Sections 4.15.7.1 and 4.15.7.2 describe the tracking services and baseband data interfaces, respectively.

#### 4.15.7.1 Tracking Services

*Table 4-48* identifies the RADAR #18 Radar System characteristics.

#### 4.15.7.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

### 4.15.8 Mobile RADAR #2 Radar System

The general characteristics of the Mobile RADAR #2 – RIR-778C Radar System at WFF are as follows:

- Location: Varies
- One 2.38-meter RADAR antenna

- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking services: RADAR
- Data Processing: Hardcopy plots of tracking versus time.

Sections 4.15.8.1 and 4.15.8.2 describe the tracking services and baseband data interfaces, respectively.

**Table 4-48. *RADAR #18 Radar Characteristics***

| Characteristic | Value |
|---|---|
| Wave Length Band | (C-band) |
| Peak Power Output | 1 MW |
| Pulse Rate Frequency | 160, 320, 640 pps |
| Beamwidth | 0.71° |
| Antenna Size | 4.88 m |
| Antenna Gain | 46 dB |
| Maximum Range | 60,000 km |
| 1-$m^2$ Skin Track | 435,000 km |
| Range Precision | 10 m |
| Angle Precision | 0.15 Mils |
| Slew Rate | AZ: 25 deg/sec<br>EL: 20 deg/sec |

#### 4.15.8.1 Tracking Services

*Table 4-49* identifies the RADAR #2 Radar System characteristics.

#### 4.15.8.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

**Table 4-49. *RADAR #2 Radar Characteristics***

| Characteristic | Value |
|---|---|
| Wave Length Band | (C-band) |
| Peak Power Output | 1 MW |
| Pulse Rate Frequency | 160, 320, 640 pps |
| Beamwidth | 3° |
| Antenna Size | 2.38 m |
| Antenna Gain | 38 dB |
| Maximum Range | 60,000 km |
| 1-$m^2$ Skin Track | 220 km |
| Range Precision | 10 m |
| Angle Precision | 0.24 Mils |
| Slew Rate | AZ: 40 deg/sec<br>EL: 40 deg/sec |

### 4.15.9 Mobile RADAR #8 Radar System

The general characteristics of the Mobile RADAR #8 – RIR-778C Radar System at WFF are as follows:

- Location: Varies
- One 2.38-meter RADAR antenna
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking services: RADAR
- Data Processing: Hardcopy plots of tracking versus time.

Sections 4.15.9.1 and 4.15.9.2 describe the tracking services and baseband data interfaces, respectively.

#### 4.15.9.1 Tracking Services

*Table 4-50* identifies the RADAR #8 Radar System characteristics.

#### 4.15.9.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

**Table 4-50. *RADAR #8 Radar Characteristics***

| Characteristic | Value |
|---|---|
| Wave Length Band | (C-band) |
| Peak Power Output | 1 MW |
| Pulse Rate Frequency | 160, 320, 640 pps |
| Beamwidth | 3° |
| Antenna Size | 2.38 m |
| Antenna Gain | 38 dB |
| Maximum Range | 60,000 km |
| 1-$m^2$ Skin Track | 220 km |
| Range Precision | 10 m |
| Angle Precision | 0.24 Mils |
| Slew Rate | AZ: 40 deg/sec<br>EL: 40 deg/sec |

### 4.15.10 Mobile RADAR #10 Radar System

The general characteristics of the Mobile RADAR #10 – RIR-778C Radar System at WFF are as follows:

- Location: Varies
- One 3.66-meter RADAR antenna
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking services: RADAR
- Baseband data interfaces: Hardcopy plots of tracking versus time.

Sections 4.15.10.1 and 4.15.10.2 describe the tracking services and baseband data interfaces, respectively.

#### 4.15.10.1 Tracking Services

*Table 4-51* identifies the RADAR #10 Radar System characteristics.

#### 4.15.10.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

### 4.15.11 Mobile RADAR #11 Radar System

The general characteristics of the Mobile RADAR #11 – RIR-778C Radar System at WFF are as follows:

- Location: Varies
- One 3.66-meter RADAR antenna
- Scheduled by WFF Range and Mission Management Office using Wallops Integrated Scheduling and Document Management System.
- Tracking services: RADAR
- Baseband data interfaces: Hardcopy plots of tracking versus time.

Sections 4.15.11.1 and 4.15.11.2 describe the tracking services and baseband data interfaces, respectively.

#### 4.15.11.1 Tracking Services

*Table 4-52* identifies the RADAR #11 Radar System characteristics.

#### 4.15.11.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

**Table 4-51.** ***RADAR #10 Radar Characteristics***

| Characteristic | Value |
|---|---|
| Wave Length Band | (C-band) |
| Peak Power Output | 1 MW |
| Pulse Rate Frequency | 160, 320, 640 pps |
| Beamwidth | 1.1° |
| Antenna Size | 3.66 m |
| Antenna Gain | 43 dB |
| Maximum Range | 60,000 km |
| 1-$m^2$ Skin Track | 425 km |
| Range Precision | 10 m |
| Angle Precision | 0.2 Mils |
| Slew Rate | AZ: 30 deg/sec<br>EL: 30 deg/sec |

**Table 4-52.** ***RADAR #11 Radar Characteristics***

| Characteristic | Value |
|---|---|
| Wave Length Band | (C-band) |
| Peak Power Output | 1 MW |
| Pulse Rate Frequency | 160, 320, 640 pps |
| Beamwidth | 1.1° |
| Antenna Size | 3.66 m |
| Antenna Gain | 43 dB |
| Maximum Range | 60,000 km |
| 1-$m^2$ Skin Track | 425 km |
| Range Precision | 10 m |
| Angle Precision | 0.2 Mils |
| Slew Rate | AZ: 30 deg/sec<br>EL: 30 deg/sec |

## 4.16 VHF Ground Stations

The two VHF Air/Ground (A/G) Ground Stations at WFF are used only to support the International Space Station and Soyuz spacecraft . The VHF-1 system can transmit and receive voice and support packet data on the uplink. The VHF-2 system supports only voice. The general characteristics of the two VHF A/G Ground Stations at WFF are as follows:

- Location: 37° N
  75° W
- Two Quad Yagi antennas (VHF-1 and VHF-2) for simultaneously transmitting voice at VHF while receiving voice at VHF.
- Manual scheduling by DSMC, but only JSC-MCC is allowed to request support.
- Tracking services: None.
- Baseband interfaces: Dedicated NISN communications voice loops.

Sections 4.16.1 and 4.16.2 describe the VHF-1 and VHF-2 A/G characteristics, respectively. Section 4.16.3 describes the baseband interfaces.

### 4.16.1 VHF-1 A/G Voice Ground Station

Tables 4-53 and 4-54 identify the A/G Full Duplex uplink and downlink characteristics of the WFF VHF-1 Ground Station, respectively.

**Table 4-53.** ***WFF VHF-1 A/G Uplink Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 139.208 MHz |
| EIRP | ≥ 45.4 dBWi |
| Polarization | TBD |
| Antenna Beamwidth | TBD |
| Antenna Gain | 20.0 dBi |
| Output Power | 350 W |
| Carrier Modulation | FM |
| FM Deviation | ± 10 kHz |
| Carrier Data Rate | TBD for packet data |

**Table 4-54.** ***WFF VHF-1 A/G Downlink Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 143.625 MHz |
| G/T | TBD |
| System Noise Temperature | TBD |
| Polarization | TBD |
| Antenna Beamwidth | TBD |
| Antenna Gain | 20.0 dBi |
| Carrier Modulation | FM |
| FM Deviation | ± 10 kHz |
| Carrier Data Rate | N/A (Voice only on downlink) |

### 4.16.2 VHF-2 A/G Voice Ground Station

Tables 4-55 and 4-56 identify the A/G Full Duplex voice uplink and downlink characteristics of the WFF VHF-2 Ground Station, respectively.

**Table 4-55.** ***WFF VHF-2 A/G Uplink Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 130.167 MHz |
| EIRP | ≥ 45.4dBWi |
| Polarization | TBD |
| Antenna Beamwidth | TBD |
| Antenna Gain | 20.0 dBi |
| Output Power | 350 W |
| Carrier Modulation | FM |
| FM Deviation | ± 10 kHz |
| Carrier Data Rate | N/A (Voice only) |

**Table 4-56.** ***WFF VHF-2 A/G Downlink Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 121.750 MHz |
| G/T | TBD |
| System Noise Temperature | TBD |
| Polarization | TBD |
| Antenna Beamwidth | TBD |
| Antenna Gain | 20.0 dBi |
| Carrier Modulation | FM |
| FM Deviation | ± 10 kHz |
| Carrier Data Rate | N/A (Voice only) |

### 4.16.3 Baseband Voice Interfaces

The WFF VHF-1 ground station can send and receive baseband voice and receive packet data from only the JSC-MCC via dedicated NISN communications voice loops. The WFF VHF-2 ground station can send and receive baseband voice only from the JSC-MCC via dedicated NISN communications voice loops.

# Section 5.  McMurdo Ground Station (MGS)

This section describes the MGS in Antarctica. The general characteristics of the station are as follows:

- Location: 77° 50′ 21″ S
  193° 19′ 59″ W
- One 10-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 5-1 is a photograph of the MGS antenna.
- Automatically scheduled by DSMC using WOTIS.
- Tracking services:  None.
- Baseband data interfaces: IP, 4800-bit blocks encapsulated in IP packets, and mail (also uses TDRS relay, which supports serial clock and data and other interfaces).

Sections 5.1 through 5.3 describe S- and X-band performance characteristics. Section 5.4 describes the baseband data interfaces.

**Figure 5-1.  MGS Antenna**

## 5.1 S-Band Command

*Table 5-1* identifies the S-band command characteristics of the MGS.

## 5.2 S-Band Telemetry

*Table 5-2* identifies the S-band telemetry characteristics of the MGS.

## 5.3 X-Band Telemetry

*Table 5-3* identifies the X-band telemetry characteristics of the MGS.

## 5.4 Baseband Data Interfaces

MGS can send and receive baseband data in either of the following formats: IP and 4800-bit blocks encapsulated in IP packets (see Sections 10.2 and 10.4, respectively). The station currently uses about 10% of a National Science Foundation T-1 communications link to support command, low-rate telemetry, and ground station control and monitor. MGS mails high-rate, tape-recorded X-band telemetry data to the user (see Section 9.5).

In addition to the baseband data options described above, MGS can relay high-rate X-band telemetry data through a Tracking and Data Relay Satellite (TDRS). MGS data is rate-buffered through the TDRS at 105 Mbps or less. At the White Sands ground station, where the TDRS relay ends, the raw data is sent to the user in one of the following formats: IP, serial clock and data, or 4800-bit blocks encapsulated in IP packets.

**Table 5-1. MGS S-Band Command Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 2025 – 2120 MHz |
| EIRP | ≥ 63 dBWi |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.05° |
| Antenna Gain | 44 dBi |
| Output Power | 200 W |
| Carrier Modulation | PM, FM, or PSK |
| Modulation Index | FM: 50 kHz – 50 MHz deviation<br>BPSK: ±90° |
| Carrier Data Rate | ≤ 200 kbps |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 32 kbps |
| Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |

**Table 5-2. MGS S-Band Telemetry Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2400 MHz |
| G/T | ≥ 21.1 dB/K |
| System Noise Temperature | 245 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 0.91° |
| Antenna Gain | 45 dBi |
| Carrier Modulation | PM, FM, AM, or BPSK |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Carrier Data Rate | NRZ-L: 100 bps – 8 Mbps<br>Biϕ-L: 100 bps – 4 Mbps |
| Carrier Data Format | NRZ-L or Biϕ-L |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 1 Mbps |
| Subcarrier Data Format | NRZ-L, M, or S; Biϕ-L, M, or S |
| Decoding | Viterbi and/or Reed-Solomon (CCSDS) |

**Table 5-3. MGS X-Band Telemetry Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 8025 – 8400 MHz |
| G/T | ≥ 32.5 dB/K |
| System Noise Temperature | 225 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 0.26° |
| Antenna Gain | 56 dBi |
| Modulation Type | QPSK or UQPSK |
| Data Rate | QPSK: 6 – 110 Mbps<br>UQPSK: 10 – 23 Mbps<br>75 – 90 Mbps |
| Data Format | NRZ-L, M, or S |
| Decoding | Viterbi and/or Reed-Solomon (CCSDS) |

# Section 6. Alaska Ground Stations

This section describes the GN stations at Poker Flat, Alaska:

- LEO-T – Alaska (Section 6.3)
- TOTS – Alaska (Section 6.4)
- AGS (Section 6.5)

## 6.1 LEO-T – Alaska

The general characteristics of the LEO-T ground station in Alaska are as follows:

- Location: 65º 07′ N
  147º 27′ W
- One 5-meter antenna for simultaneously transmitting and receiving at S-band. Figure 6-1 is a photograph of the LEO-T antenna.
- Automatically scheduled by DSMC using WOTIS (see Section 9.3).
- Tracking services: None.
- Baseband data interface: IP.

Sections 6.1.1 and 6.1.2 describe S-band performance characteristics, and Section 6.1.3 describes the baseband data interface.

### 6.1.1 S-Band Command

*Table 6-1* identifies the S-band command characteristics of the LEO-T – Alaska station.

### 6.1.2 S-Band Telemetry

*Table 6-2* identifies the S-band telemetry characteristics of the LEO-T – Alaska station.

### 6.1.3 Baseband Data Interfaces

The LEO-T – Alaska station can send and receive baseband data in the IP format only (see Section 10.2). The station currently has a T-1 (1.544 Mbps) communications link with GSFC/WFF to support command, low-rate telemetry, and ground station control and monitor.

**Figure 6-1. LEO-T - Alaska Antenna**

**Table 6-1.** ***LEO-T – Alaska S-Band Command Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2025 – 2120 MHz |
| EIRP | ≥ 59.2 dBWi |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.8° |
| Antenna Gain | 38.6 dBi |
| Output Power | 200 W |
| Carrier Modulation | PM, BPSK, or FM |
| Modulation Index | PM: 0.2 - 1.5 radians (peak) |
| Carrier Data Rate | ≤ 200 kbps |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 32 kbps |
| Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |

**Table 6-2.** ***LEO-T – Alaska S-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2300 MHz |
| G/T | ≥ 17 dB/K |
| System Noise Temperature | 174 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.83° |
| Antenna Gain | 39.4 dBi |
| Carrier Modulation | PM, FM, BPSK, or QPSK |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Carrier Data Rate | Uncoded: 8 Mbps<br>Rate-½ coded: 4 Mbps |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 4 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 1 Mbps |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi and/or Reed-Solomon (CCSDS) |

## 6.2 TOTS – Alaska

The general characteristics of the TOTS ground station in Alaska are as follows:

- Location: 65º 07′ 02″ N
  147º 27′ 33″ W
- One 8-meter antenna for simultaneously transmitting and receiving at S-band. Figure 6-2 is a photograph of the TOTS antenna.
- Automatically scheduled by DSMC using WOTIS (see Section 9.3).
- Tracking services: 1- & 2-way Doppler and antenna autotracking angle.
- Baseband data interfaces: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets.

Sections 6.2.1 and 6.2.2 describe S-band performance characteristics. Sections 6.2.3 and 6.2.4 describe the tracking services and baseband data interfaces, respectively.

**Figure 6-2. TOTS - Alaska Antenna**

### 6.2.1 S-Band Command

*Table 6-3* identifies the S-band command characteristics of the TOTS – Alaska station.

### 6.2.2 S-Band Telemetry

*Table 6-4* identifies the S-band telemetry characteristics of the TOTS – Alaska station.

**Table 6-3.** ***TOTS – Alaska S-Band Command Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2025 – 2120 MHz |
| EIRP | ≥ 62 dBWi |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.27° |
| Antenna Gain | 42.1 dBi |
| Output Power | 200 W |
| Carrier Modulation | PM, FM, or PSK |
| Modulation Index | PM: 0 – 1.5 radians (peak)<br>FM: 50 kHz – 50 MHz<br>BPSK: ±90° |
| Carrier Data Rate | ≤ 200 kbps |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 32 kbps |
| Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |

### 6.2.3 Tracking Services

#### 6.2.3.1 Doppler Tracking

The TOTS – Alaska station generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the TOTS – Alaska S-band up-link signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in *Table 6-5*.

#### 6.2.3.2 Antenna Autotracking Angle Data

TOTS – Alaska can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in Section 1.3, above.)

**Table 6-4. *TOTS – Alaska S-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2400 MHz |
| G/T | ≥ 21 dB/K |
| System Noise Temperature | 150 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1.14° |
| Antenna Gain | 42.8 dBi |
| Carrier Modulation | PM, FM, BPSK, or AM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Carrier Data Rate | ≤ 4 Mbps |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 1 Mbps |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi and/or Reed-Solomon (CCSDS) |

### 6.2.4 Baseband Data Interfaces

The TOTS – Alaska station can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Sections 10.2, 10.3, and 10.4, respectively). The station currently has a T-1 (1.544 Mbps) communications link with GSFC/WFF to support command, low-rate telemetry, and ground station control and monitor.

**Table 6-5.** ***TOTS – Alaska Doppler Tracking Characteristics***

| Characteristic | Value |
|---|---|
| Counter Resolution | 0.001 cycles |
| Doppler Frequency Shift | ≤ 0.25 MHz |
| Doppler Bias Frequency | 0.24 MHz |
| Drift ($\Delta f/f$) | $4x10^{-11}$ at 0.1 seconds |
| Accuracy | 0.01 Hz |
| Output Equation | $1000\ (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$ |

## 6.3 AGS

This section describes the EOS Polar Ground Station located at Poker Flat, Alaska, known as the Alaska Ground Station (AGS).

The general characteristics of the station are as follows:

- Location: 65º 07′ 00″ N<br>147º 27′ 42″ W
- One 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-3 is a photograph of the AGS antenna.
- Automatically scheduled by DSMC using WOTIS (see Section 9.3).
- Tracking services: 1- & 2-way Doppler and antenna autotracking angle.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 6.3.1 through 6.3.3 describe S- and X-band performance characteristics. Sections 6.3.4 and 6.3.5 describe the tracking services and baseband data interfaces, respectively.

### 6.3.1 S-Band Command

Table 6-16 identifies the S-band command characteristics of the AGS.

### 6.3.2 S-Band Telemetry

*Table 6-7* identifies the S-band telemetry characteristics of the AGS.

### 6.3.3 X-Band Telemetry

*Table 6-8* identifies the X-band telemetry characteristics of the AGS.

**Figure 6-3. AGS Antenna**

**Table 6-6.** ***AGS S-Band Command Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2025 – 2120 MHz |
| EIRP | ≥ 66 dBWi |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 0.95° |
| Antenna Gain | 44.8 dBi |
| Output Power | 200 W |
| Carrier Modulation | PM, FM, or BPSK |
| Modulation Index | PM: 1.5 radians (peak)<br>FM: 50 kHz – 50 MHz deviation<br>BPSK: ±90° |
| Carrier Data Rate | ≤ 200 kbps |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 32 kbps |
| Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |

**Table 6-7.** ***AGS S-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2400 MHz |
| G/T | ≥ 23 dB/K |
| System Noise Temperature | 190 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 0.85° |
| Antenna Gain | 45.8 dBi |
| Carrier Modulation | PM, FM, BPSK, or AM |
| Modulation Index | PM: 0.2 – 2.8 radians (peak) |
| Carrier Data Rate | NRZ: 100 bps - 8 Mbps<br>Biϕ: 100 bps - 4 Mbps |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | ≤ 2 MHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | ≤ 1 Mbps |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Viterbi and/or Reed-Solomon (CCSDS) |

### 6.3.4 Tracking Services

#### 6.3.4.1 Doppler Tracking

The AGS generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the AGS S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in *Table 6-9*.

#### 6.3.4.2 Antenna Autotracking Angle Data

The AGS can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in Section 1.3, above.)

**Table 6-8. *AGS X-Band Telemetry Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 8000 – 9000 MHz |
| G/T | ≥ 36 dB/K (at 60° elevation) |
| System Noise Temperature | 150 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 0.23° |
| Antenna Gain | 57.6 dBi |
| Modulation | QPSK, SQPSK, UQPSK, or AQPSK |
| Data Rate | 6 – 150 Mbps |
| Data Format | NRZ-L or M |
| Decoding | Viterbi (R-½) and/or Reed-Solomon |

### 6.3.5 Baseband Data Interfaces

The AGS can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Sections 10.2, 10.3, and 10.4, respectively). AGS currently has a T-1 (1.544 Mbps) communications link and OC-1 (52 Mbps) communications link with GSFC to support command, telemetry, and ground station control and monitor. AGS will also mail high-rate, tape-recorded X-band telemetry data to the user as required (see Section 10.5).

**Table 6-9.** ***AGS Doppler Tracking Characteristics***

| Characteristic | Value |
|---|---|
| Counter Resolution | 0.001 cycles |
| Doppler Frequency Shift | $\leq$ 0.23 MHz |
| Doppler Bias Frequency | 0.24 MHz |
| Drift ($\Delta f/f$) | $4 \times 10^{-11}$ at 0.1 seconds |
| Accuracy | 0.01 Hz |
| Output Equation | $1000 (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$ |

# Section 7. Florida Ground Stations

This section describes the two GN stations in Florida:

- MILA (Section 7.1)
- PDL (Section 7.2)

## 7.1 MILA

This section describes the MILA ground station, located in the Kennedy Space Center (KSC) on Merritt Island, Florida. MILA is a part of NASA's Ground Network, and was formerly part of the Spaceflight Tracking and Data Network (STDN).

The general characteristics of the station are as follows:

- Location (each antenna): 28º 30′ 29.4″ N
  80º 41′ 33.9″ W

  28º 30′ 29.4″ N
  80º 41′ 36.2″ W
- Two 9-meter antennas for simultaneously transmitting and receiving at S-band. Figure 7-1 is a photograph of the MILA Ground Station.

  (Also: two UHF antennas, one Quad-Helix and one Teltrac, for voice communications with the Space Shuttle Orbiter. For further information, telephone the MILA Operations Manager: 407-867-3515.)
- Scheduled by the DSMC at WSC (see Section 9.3).
- Tracking services: 1- & 2-way Doppler, ranging, and antenna autotracking angle.
- Baseband data interfaces: IP and 4800-bit blocks encapsulated in IP packets.

Sections 7.1.1 and 7.1.2 describe the S-band performance characteristics. Sections 7.1.3 and 7.1.4 describe the tracking services and baseband data interfaces, respectively.

### 7.1.1 S-Band Command

*Table 7-1* identifies the S-band command characteristics of MILA.

### 7.1.2 S-Band Telemetry

*Table 7-2* identifies the S-band telemetry characteristics of MILA.

**Figure 7-1.  MILA Ground Station**

**Table 7-1.  MILA S-Band Command Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 2025 – 2120 MHz |
| EIRP | 16 W: ≥ 55 dBWi<br>200 W: ≥ 63 dBWi |
| Polarization | RHC or LHC |
| Antenna Beamwidth | 1° |
| Antenna Gain | 44 dBi |
| Output Power | 16 W and 200 W (continuously variable from 100 W to 200 W) (variable from 200 mW to 2nW for testing) |
| Carrier Modulation | PM, FM, or PSK |
| Modulation Index | PM: 1 – 3 radians (peak)<br>FM: 1 MHz |
| Carrier Data Rate | 32 kbps, 72 kbps, 96 kbps, or 216 kbps |
| Carrier Data Format | NRZ-L, M, or S; Biϕ-L, M, or S |
| Subcarrier Frequency | 2 – 16 kHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | 100 bps – 8 kbps |
| Subcarrier Data Format | NRZ-L, M, or S; Biϕ-L, M, or S |

### 7.1.3 Tracking Services

#### 7.1.3.1 Doppler Tracking

MILA generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the MILA S-band uplink signal. Doppler tracking characteristics are shown in *Table 7-3*.

#### 7.1.3.2 Range Tracking

MILA range tracking service is available only for coherent two-way operation using a ranging code. Range tracking characteristics are shown in *Table 7-4*.

**Table 7-2. MILA S-Band Telemetry Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2300 MHz |
| G/T | 24 dB/K (at zenith) |
| System Noise Temperature | 100 K |
| Polarization | RHC or LHC |
| Antenna Beamwidth (3-dB) | 1° |
| Antenna Gain | 44 dBi |
| Carrier Modulation | PCM/PSK/PM, PCM/PSK/FM, PSK/FM, PCM/FM, PCM/PM, or FM/FM |
| Modulation Index | PM: 0.2 – 1.4 radians (peak) |
| Carrier Data Rate | NRZ: 100 bps – 10 Mbps<br>Biϕ: 100 bps – 5 Mbps |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | 1 – 5000 kHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | 100 bps – 2 Mbps |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Reed-Solomon (CCSDS) and/or<br>STS-TDRS mode Viterbi decoders (Rate-1/3) |

**Table 7-3. MILA Doppler Tracking Characteristics**

| Characteristic | Value |
|---|---|
| Counter Resolution | 0.001 cycles |
| Doppler Frequency Shift | ≤ 0.23 MHz |
| Doppler Bias Frequency | 0.24 MHz |

**Table 7-4. MILA Range Tracking Characteristics**

| Characteristic | Value |
|---|---|
| Operational Mode | Coherent |
| Range Code Waveform | Sine wave |
| Modulation Index | 0.2 – 1.5 radians (peak) on main carrier<br>0.3 – 1.2 radians (peak) on 1.7-MHz subcarrier |
| Major Tone Frequencies | 500 kHz, 100 kHz, and 20 kHz |
| Minor Tone Frequencies | 100 kHz, 20 kHz, and 4 kHz on carrier<br>800 Hz, 160 Hz, 40 Hz, and 10 Hz on 4-kHz subcarrier<br>(800-Hz tone transmitted single-sideband suppressed, other tones transmitted double-sideband suppressed) |
| $C_{received}/N$ | ≥ 10 dB |
| Acquisition Sequence | Major tone first, then high-to-low for minor tones |
| Acquisition Threshold, Range Tone SNR | 15 dB-Hz |
| Accuracy | 1.0 m |
| Unambiguous Range | ≤ 644,000 km (one-way) |

#### 7.1.3.3 Antenna Autotracking Angle Data

MILA can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in Section 1.3, above.)

### 7.1.4 Baseband Data Interfaces

MILA can send and receive baseband data in either of the following formats: IP and 4800-bit blocks encapsulated in IP packets (see Sections 10.2 and 10.4, respectively). MILA currently has two 224 kbps communications links with GSFC to support commanding, low-rate telemetry, and ground station control and monitor.

## 7.2 PDL

This section describes the PDL ground station in Florida. Like MILA, PDL is a part of the GN. The station provides communications to the Space Shuttle Orbiter during launch, when the plume from the solid rocket motor blocks radio signals to MILA.

The general characteristics of the station are as follows:

- Location: 29º 4′ 00″ N<br>80º 54′ 47″ W
- One 4.3-meter antenna for simultaneously transmitting and receiving at S-band. Figure 7-2 is a photograph of the PDL Ground Station.

  (Also: one fixed UHF cross-dipole antenna, optimized for high inclination launches, backup voice communications with the Space Shuttle Orbiter. The UHF system is used to backup the S-band system. For further information, telephone the MILA Operations Manager: 407-867-3515.)
- Scheduled by the DSMC at WSC (see Section 9.3).
- Tracking services: None.
- Baseband data interfaces: IP and 4800-bit blocks encapsulated in IP packets.

Sections 7.2.1 and 7.2.2 describe the S-band performance characteristics, and Section 7.2.3 describes the baseband data interfaces.

### 7.2.1 S-Band Command

*Table 7-5* identifies the S-band command characteristics of PDL.

### 7.2.2 S-Band Telemetry

*Table 7-6* identifies the S-band telemetry characteristics of the PDL.

### 7.2.3 Baseband Data Interfaces

PDL can send and receive baseband data in either of the following formats: IP and 4800-bit blocks encapsulated in IP packets (see Sections 10.2 and 10.4, respectively). The station currently has two 224 kbps communications links with the GSFC to support command.

**Figure 7-2. PDL Ground Station**

**Table 7-5. PDL S-Band Command Characteristics**

| Characteristic | Value |
|---|---|
| Frequency | 2025 – 2120 MHz |
| EIRP | 16 W: ≥ 47 dBWi<br>200 W: ≥ 58 dBWi |
| Polarization | RCP or LCP |
| Antenna Beamwidth | 2.5° |
| Antenna Gain | 37 dBi |
| Output Power | 16 W and 200 W (continuously variable from 100 W to 200 W) |
| Carrier Modulation | PM |
| Modulation Index | 0 – 3.0 radians (peak) |
| Subcarrier Frequency | 2 kHz, 4 kHz, 8 kHz, or 16 kHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | 16 bps – 8 kbps |
| Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |

## Table 7-6. PDL S-Band Telemetry Characteristics

| Characteristic | Value |
|---|---|
| Frequency | 2200 – 2300 MHz |
| G/T | 11 dB/K (at 45°) |
| System Noise Temperature | 250 K |
| Polarization | RCP or LCP |
| Antenna Beamwidth | 2.5° |
| Antenna Gain | 35 dBi |
| Carrier Modulation | PCM/PSK/PM, PCM/PM, PCM/PSK/FM, PSK/FM, PCM/FM, or FM/FM |
| Modulation Index | PM: 0.2 – 1.4 radians (peak) |
| Carrier Data Rate | 4 bps – 2000 kbps |
| Carrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Subcarrier Frequency | 1 – 2000 kHz |
| Subcarrier Modulation | BPSK |
| Subcarrier Data Rate | (Subcarrier Frequency)/(Subcarrier Data Rate) > 1.5 |
| Subcarrier Data Format | NRZ-L, M, or S; or Biϕ-L, M, or S |
| Decoding | Reed-Solomon (CCSDS) and/or<br>STS-TDRS Mode Viterbi decoders (Rate-1/3) |

# Section 8. White Sands Complex VHF Ground Stations

The two VHF Air/Ground (A/G) Ground Stations at the White Sands Complex (WSC) are used only to support the International Space Station and Soyuz spacecraft. The VHF-1 system can transmit and receive voice and support packet data on the uplink. The VHF-2 system supports only voice. The general characteristics of the two VHF A/G Ground Stations at WSC are as follows:

- Location: 32° N<br>106° E
- Single Yagi antenna (VHF-1) and Quad Yagi (VHF-2) for simultaneously transmitting voice at VHF while receiving voice at VHF.
- Manual scheduling, but only JSC-MCC is allowed to request support.
- Tracking services: None.
- Baseband interfaces: Dedicated NISN communications voice loops.

Sections 8.1 and 8.2 describe the VHF-1 and VHF-2 A/G characteristics, respectively. Section 8.3 describes the baseband interfaces.

## 8.1 VHF-1 A/G Ground Station

Tables 8-1 and 8-2 identify the A/G Full Duplex uplink and downlink characteristics of the WSC VHF-1 Ground Station, respectively.

**Table 8-1.** ***WSC VHF-1 A/G Uplink Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 139.208 MHz |
| EIRP | ≥ 43.4 dBWi |
| Polarization | TBD |
| Antenna Beamwidth | TBD |
| Antenna Gain | 18.0 dBi |
| Output Power | 350 W |
| Carrier Modulation | FM |
| FM Deviation | ± 10 kHz |
| Carrier Data Rate | TBD for packet data |

**Table 8-2.** ***WSC VHF-1 A/G Downlink Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 143.625 MHz |
| G/T | TBD |
| System Noise Temperature | TBD |
| Polarization | TBD |
| Antenna Beamwidth | TBD |
| Antenna Gain | 20.0 dBi |
| Carrier Modulation | FM |
| FM Deviation | ± 10 kHz |
| Carrier Data Rate | N/A (Voice only on downlink) |

## 8.2 VHF-2 A/G Voice Ground Station

Tables 8-3 and 8-4 identify the A/G Full Duplex voice uplink and downlink characteristics of the WSC VHF-2 Ground Station, respectively.

**Table 8-3.** ***WSC VHF-2 A/G Uplink Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 130.167 MHz |
| EIRP | ≥ 45.4dBWi |
| Polarization | TBD |
| Antenna Beamwidth | TBD |
| Antenna Gain | 20.0 dBi |
| Output Power | 350 W |
| Carrier Modulation | FM |
| FM Deviation | ± 10 kHz |
| Carrier Data Rate | N/A (Voice only) |

**Table 8-4. *WSC VHF-2 A/G Downlink Characteristics***

| Characteristic | Value |
|---|---|
| Frequency | 121.750 MHz |
| G/T | TBD |
| System Noise Temperature | TBD |
| Polarization | TBD |
| Antenna Beamwidth | TBD |
| Antenna Gain | 20.0 dBi |
| Carrier Modulation | FM |
| FM Deviation | ± 10 kHz |
| Carrier Data Rate | N/A (Voice only) |

## 8.3 Baseband Voice Interfaces

The WSC VHF-1 ground station can send and receive baseband voice and receive packet data from only the JSC-MCC via dedicated NISN communications voice loops. The WSC VHF-2 ground station can send and receive baseband voice only from the JSC-MCC via dedicated NISN communications voice loops.

# Section 9. Scheduling

## 9.1 Introduction

This section describes the following options for scheduling support:

- Automated Scheduling
- Manual Scheduling.

## 9.2 The Wallops Orbital Tracking Information System (WOTIS)

WOTIS is the GN scheduling system which is located at the Data Services Management Center (DSMC) located at the White Sands Complex near Las Cruces, NM. Using either automated or manual processes, all orbital apertures are scheduled through the WOTIS.

WOTIS is composed of the following three elements depicted in Figure 9-1:

**a. Wallops Information System Access (WISAC)**

All incoming and outgoing scheduling files pass through WISAC via FTP or e-mail. Some file reformatting is done at WISAC, if necessary. WISAC uses UNIX scripting; therefore, all functions are handled automatically. Each user is assigned a mailbox on WISAC.

**b. Wallops Orbital Tracking Resource Scheduler (WOTRS)**

WOTRS is the core scheduling system. Input to WOTRS is in the form of either a generic request file (see Section 9.2.1) or a specific request file (see Section 9.2.2). The output is the "official" schedules that are sent to the GN stations, users, and WISDB via WISAC.

**c. Wallops Information System Database (WISDB)**

WISDB is the central database that tracks every support throughout its life. WOTRS uses the "official" schedules to determine what is scheduled at any given time at all GN stations that use WOTIS. Spacecraft pass results from the GN stations flow into WISDB via WISAC. WISDB then provides pass reports to the users.

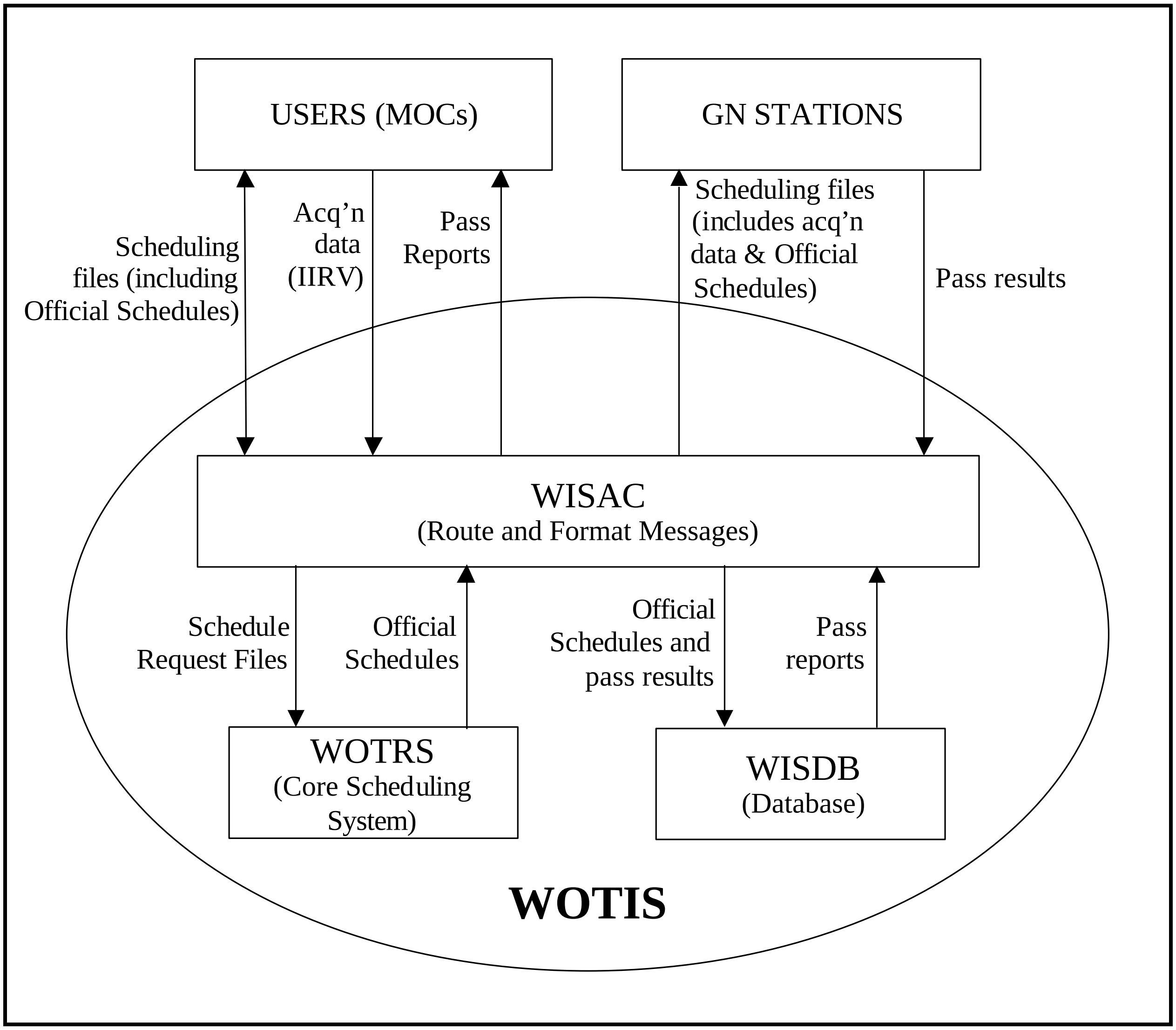


**Figure 9-1. WOTIS Functional Diagram**

## 9.3 Scheduling Process

The scheduling process is initiated by customers using either the generic or specific scheduling processes. The following is a description of the scheduling weeks:

Strawman week

- 3 weeks in the future
- Composition of all possible views for selected customers

Forecast week

- 2 weeks in the future Schedules are created based on customer requests
- 95% conflict resolution performed
- GN priority list is used

Operations week

- 1 week in the future
- Only the "absolute priorities" in the GN Priority list are used

Realtime week

- This is the active week
- No routine schedule changes should occur
- Only the "absolute priorities" in the GN Priority list are used
- Demand maintenance and critical test activities are accommodated

### 9.3.1 Generic Scheduling

With generic scheduling, the Mission Operations Center (MOC) sends its *generic* scheduling requirements to DSMC. Customer view periods are created by the project, FDF, or the schedulers using Satellite Tool Kit (STK). Generic scheduling is also known as rule-based scheduling.

Typical generic scheduling requirements include a subset of the following:

- Minimum number of supported passes per day.

- Minimum amount of time supported per pass (specified separately for telemetry and command).
- Minimum and/or maximum amount of time between supported passes.
- GN station(s) providing support.
- Minimum number of GN stations required to support a pass during a specified time interval (for example: “At least two different GN stations for the period between 2200Z and 0500Z”).
- Minimum ground antenna elevation angle.

*Table 9-1* presents a typical generic scheduling timeline.

### 9.3.2 Specific Scheduling

If a mission chooses to use specific scheduling, the MOC requests the *specific* GN station and the *specific* start and end times of the pass. The MOC submits the schedule every week. *Table 9-2* provides an example of specific scheduling. (DSMC prefers generic scheduling because it optimizes the use of shared GN resources.)

### 9.3.3 WOTIS Scheduling During DSMC Emergency Evacuations

If an emergency evacuation or other unplanned event occurs at WSC and the WOTIS network is shut down, all scheduling files, such as the Master File in Table 9-1, will not be sent automatically. Each MOC (user) will need to directly send its scheduling requirements to the ground stations via telephone and/or e-mail. Spacecraft post-pass results files will not be sent to the MOC (user) until the WOTIS network is re-stored. However, post-pass results files are not mission critical.

If a minor evacuation event causes DSMC personnel to leave WOTIS unattended, but with the WOTIS network still running, automated scheduling files, such as the Master File, will still be processed and sent to the ground stations. However, if the MOC (User) requires any additions, deletions, or other final changes to the Master file when DSMC personnel are not available, the MOC will need to directly contact the ground station by telephone.

**Table 9-1.** ***Generic Scheduling Timeline***

| Time | Message | Source ® Destination | Notes |
|---|---|---|---|
| 2 – 3 weeks before target | Strawman Schedule file | WOTIS → MOC<br>(via FTP) | Preliminary schedule<br>Contains initial supports at GN station in accordance with agreed-upon scheduling rules<br>Generated weekly |
| 2 – 3 weeks before target | Update to Strawman Schedule file<br>(optional) | MOC → WOTIS<br>(via FTP) | Not needed if Strawman Schedule is correct<br>Deletes supports not needed by MOC<br>MOC may adjust times and activity codes<br>MOC may request a new support |
| 1 week before target | Official Schedule file | WOTIS → MOC | Sent if MOC requires<br>Final operations schedule<br>Contains supports that will be sent to GN station<br>Generated on Tuesday |
| Daily, as needed | Master file<br>(GN station Official Schedule) | WOTIS → GN station<br>(via FTP) | Weekly and/or daily schedule<br>Covers 1 week<br>Generated on Thursday/Friday<br>Contains ephemeris |

### 9.3.4 Manual Scheduling

With manual scheduling, DSMC personnel perform the scheduling without automated support from WOTIS. SATAN, SCAMP, METEOSAT, and TOTS in Alaska use manual scheduling exclusively. The WFF Range and Mission Management Office schedules range support. The process is as follows:

a. MOC and DSMC agree on the schedule via e-mail and telephone.

b. DSMC e-mails the schedule to the GN station operators.

c. GN station operators manually configure the equipment for the scheduled pass.

**Table 9-2.** ***Specific Scheduling Timeline***

| Time | Message | Source ® Destination | Notes |
|---|---|---|---|
| 3 weeks before target week | Strawman Request file | MOC → WOTIS | Begins the scheduling process<br>MOC's best-guess estimate of mission support needs for the target week<br>Covers 1 week, with 1 day of overlap on each end |
| 2½ weeks before first day of target week | Forecast Schedule file | WOTIS → MOC | Preliminary schedule<br>Sent on Thursday<br>Covers 1 week, with 1 day of overlap on each end |
| 1 to 2 weeks before target week | Confirmed Schedule<br>(optional) | MOC → WOTIS | Eliminates unnecessary support from the Forecast Schedule<br>Covers 1 week, with 1 day of overlap on each end<br>If the Forecast Schedule provides insufficient mission support, MOC and WOTIS operators negotiate via voice and/or e-mail |
| > 4 hours before beginning of target day | Daily Official Schedule file | WOTIS → MOC | Covers 48 hours: the target day and the following day (for overlap)<br>Sent every day no later than 2000Z<br>First support period starts after 0000Z<br>Updates the database at WOTIS<br>Automatically and immediately updates information at the GN station sites |
| > 4 hours before beginning of target day | Master Official Schedule file | WOTIS → GN station<br>WOTIS → MOC | Support period is automatically added to the GN station schedule (without operator intervention)<br>Covers at least 24 hours, often several days to a week |
| < 4 hours before beginning of target day | Schedule changes<br>(optional) | MOC → GN station | Additions and modifications to the master official schedule<br>Voice communications between the MOC and the GN station operators<br>Confirmed via e-mail |

## 9.4. Scheduling Pre-Mission Test and Launch Support

GN Performance Analyst Office (GN PAO) schedules GN resources for pre-mission test and launch support as follows:

**a. <u>Scheduling Pre-Mission Test Support</u>**

Depending on the type of pre-mission test that the user requests, the Network Operations Manager (NOM), STDN Mission Manager (SMM) and/or the Test Director (TD), in conjunction with the user, determine the pre-mission test technical details. Then the NOM, SMM, and/or TD provide GN PAO with the relevant technical details, including schedule requirements, supporting stations, and support requirements. GN PAO identifies and resolves resource conflicts pre-mission tests may have with activities already on GN schedules.

**b. <u>Scheduling Launch Support</u>**

When scheduling launch support, the Customer Service Representative and NOM, in conjunction with the customer, provide GN PAO and DSMC Scheduling with the following:

(1) Launch schedule requirements.

(2) GN stations required by the mission during launch.

(3) Launch and early orbit support requirements.

## 9.5 Ground Network Priority List

The primary method for conflict resolution is negotiation between users and resources. If there is an impasse or insufficient time for negotiations, the schedulers use the GN Priority List to resolve the conflict.

# Section 10. Baseband Data Interfaces And Storage

## 10.1 Introduction

This section describes the baseband data interface and storage equipment options at the GN stations:

a. NISN IP Network

b. Serial Clock and Data

c. 4800-Bit Block Encapsulated in IP Packets

d. Mail Delivery of Recorded Data

e. Standard Autonomous File Server (SAFS)

*Table 10-1* summarizes the baseband data interfaces available at each station; an "X" means that capability is offered.

## 10.2 NISN IP Network

For those GN stations that support it, the NISN IP Network can be used by MOCs to send commands to and receive telemetry data from a GN station.

**a. <u>Open and Closed Networks</u>**

The NISN IP Network uses both open and closed NASA IP networks. "Open" and "closed" are relative – both are secure. Although the closed network provides more security, the open network is still inaccessible to the public. A firewall (or "gateway") is used when data crosses an open/closed boundary in either direction.

**b. <u>TCP/IP and UDP/IP</u>**

The NISN IP Network supports both Transmission Control Protocol/Internet Protocol (TCP/IP) and User Datagram Protocol/Internet Protocol (UDP/IP).

Figure 9-1 depicts the TCP/IP layer model. Each layer is encapsulated by the next lower level. "Encapsulation" is the addition of a control information header and/or trailer to a block of data. For example, in Figure 10-1, the Internet Protocol Data Unit (IPDU) packet encapsulates the Channel Access Data Unit (CADU) packet. For UDP/IP, the layering is identical to Figure 10-1, except the TCP layer is replaced by a UDP layer.

**c. <u>Packets and Layers</u>**

*CADU* and Command Link Transmission Unit (*CLTU*) packets are Consultative Committee for Space Data Systems (CCSDS)-compliant telemetry and command data unit protocols, respectively. (See Reference [p] in Section 1.3 for more information on CADUs and CLTUs.) For commands, the CADU layer in Figure 10-1 is replaced by a CLTU layer.

**Table 10-1.** ***Baseband Data Interface Options***

| Station | NISN IP Network | Serial Clock and Data | 4800-Bit Blocks Encapsulated in IP Packets | Mail Delivery |
|---|---|---|---|---|
| SGS | X | X | X | X |
| WGS | X | X | X | X |
| LEO-T – WFF | X | X | X | |
| TOTS – WFF | X | X | X | |
| MGTAS | X | | X | |
| SATAN* | X | | X | |
| SCAMP* | | | | |
| METEOSAT** | | | | |
| Mobile Systems | | | | X |
| Radar Systems | | | | X |
| MGS | X | X (via MTRS and White Sands) | X | X |
| LEO-T – Alaska | X | | | |
| TOTS – Alaska | X | X | X | |
| AGS | X | X | X | X |
| MILA | X | | X | |
| PDL | X | | X | |

* Users conduct SATAN and SCAMP transmissions by requesting commands via telephone or e-mail with the GN station directly.

** METEOSAT records received data onto computer disks, then sends it via telephone. METEOSAT does not use NASCOM or NISN data circuits.

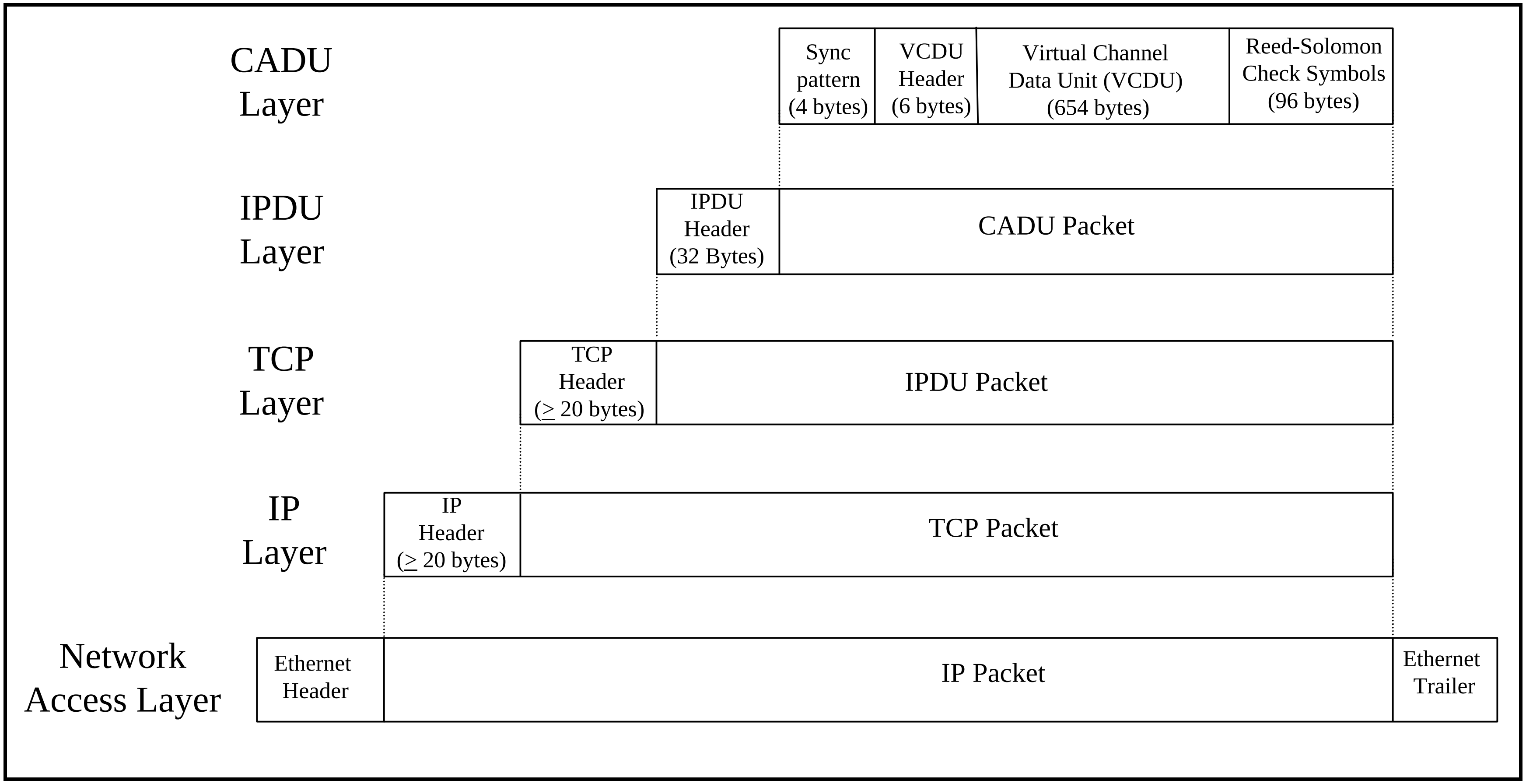


**Figure 10-1. NISN IP Network Layers***

* <u>TCP</u>/IP layers are shown; <u>UDP</u>/IP is identical, except "TCP" is replaced by "UDP."

<u>Telemetry</u> packets are shown; <u>command</u> packets are identical, except "CADU" is replaced by "CLTU."

The *IPDU* packet is a NASA protocol (see Reference [q] for a detailed description). The *Network Access* Layer is a protocol format that provides physical access to NISN. For the GN stations that support IP data transfer, the Network Access Layer is the Ethernet protocol that interfaces the GN station to the Routers. The *IP Layer* allows data to traverse multiple networks between users and the GN station. IP alone does not ensure that the data will be delivered, but when IP is used with *TCP*, all data is guaranteed to be delivered. TCP is a virtual connection protocol designed to work with IP. It provides reliable communication across a variety of both reliable and unreliable networks and internets. Reference [r] fully describes the TCP, IP, and Network Access Layers of an IP network.

**d. UDP**

UDP is available to users who want faster data transfers than TCP provides. UDP is unreliable, however, because – unlike TCP – it doesn't provide the handshaking protocols that guarantee delivery.

**e. PTP Encapsulation**

Except for the two LEO-T stations, all GN stations that support IP use Programmable Telemetry Processors (PTPs) to perform encapsulation and de-encapsulation (Reference [g] describes the PTP in detail). In addition to IPDU, the PTP supports several other packet formats for encapsulating CLTUs or CADUs prior to the TCP or UDP layers. PTPs offer the following packet format choices:

- IPDU
- Advanced X-ray Astrophysics Facility (AXAF) Standard Formatted Data Unit (SFDU)
- Deep Space-Terminal (DS-T) SFDU
- Advanced Composition Explorer (ACE) SFDU
- LEO-T Telemetry Frame Delivery Header (TFDH)
- LEO-T Command Delivery Header (CDH)
- NASCOM Real-time Transmission Protocol (RTP)
- No extra encapsulation between the CADU or CLTU layer and the TCP or UDP layer

Instead of a PTP, the LEO-T stations use a front-end processor that offers encapsulation and format choices that are a subset of the PTP's.

### 10.2.1 Command Data (Real-Time)

The MOC sends real-time command data to the GN station via the NISN IP Network. Either TCP/IP or UDP/IP sockets may be used.

About fourteen minutes prior to each command service (assuming TCP/IP data transfer), the MOC initiates two TCP/IP socket connections with the GN station: one socket for command data, the other for command echoes. If the user does not require command echo service, the MOC need not initiate the second socket.

### 10.2.2 S-Band Telemetry Data

About fourteen minutes prior to each S-band telemetry service (assuming TCP/IP data transfer), the MOC initiates two independent TCP/IP socket connections with the GN station: one socket for telemetry data on the main carrier, the other for data on the subcarrier. The MOC needs to initiate only one socket if the user vehicle transmits only one stream of telemetry data.

## 10.3 Serial Clock and Data

The serial clock and data option is the transmission and/or reception of raw digital data streams with associated clock signals.

## 10.4 4800-Bit Block Encapsulated in IP Packets

NASA is currently converting its remaining 4800-bit block point-to-point serial circuits to an IP-based network. The new NISN IP Network, however, will remain backward compatible with MOCs and other facilities that support only NASCOM 4800-bit-block serial clock and data transport. GN stations will provide legacy support to users who require the 4800-bit-block service by providing conversion devices that encapsulate 4800-bit blocks in UDP/IP datagrams. At GSFC, conversion devices will de-encapsulate the 4800-bit blocks and send them to the user over serial data circuits. Sections 10.4.1 through 10.4.5 describe this 4800-bit block format, depicted in Figure 10-2.

### 10.4.1 Network Header

The first 48 bits in the 4800-bit block contain the NASCOM synchronization code, routing, and block-accounting information, as described below:

a. **Bits 1-24 (NASCOM Synchronization Code)**

   A fixed, 24-bit code ($627627_{16}$).

b. **Bits 25-32 (Source)**

   An 8-bit, NASCOM-assigned code that identifies the sender by geographic location.

c. **Bits 33-40 (Destination)**

   An 8-bit, NASCOM-assigned code that identifies the geographic destination (one or multiple destinations).

d. **Bits 41-43 (Block Sequence Number)**

   A 3-bit code that identifies the block’s location in a sequence of blocks. This enables the destination system to place each block in its proper order.

**e. Bits 44-48 (Format Code)**

A 5-bit code that identifies the type of data in the Data Field: telemetry, real-time commands, tracking data, or non-real-time commands.

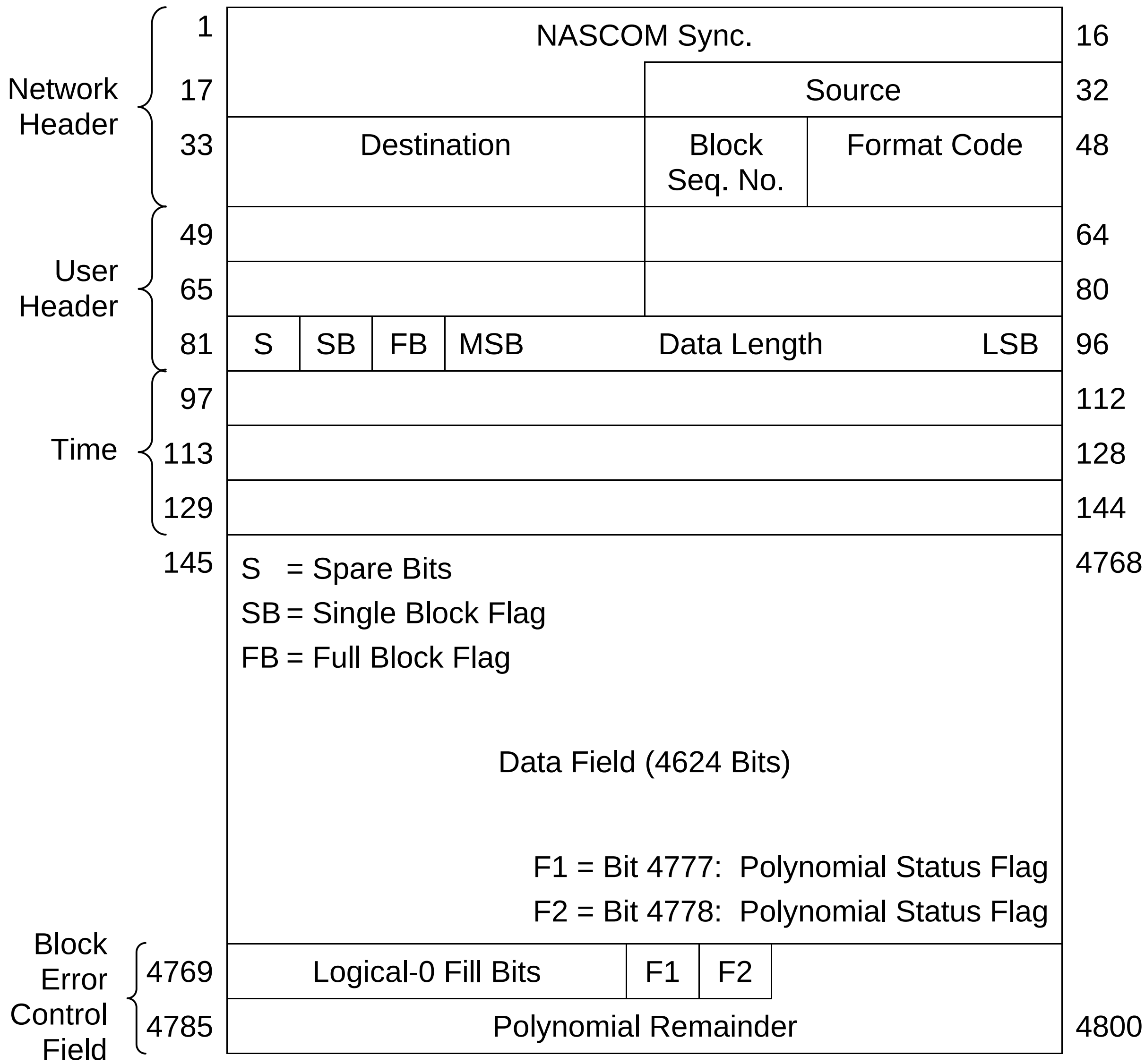


**Figure 10-2. NASCOM 4800-Bit Block Format**

### 10.4.2 User Header

A 48-bit field that contains sender-supplied information that the destination system requires to route and process the data.

### 10.4.3 Time

A 48-bit code that provides the Universal Time Coordinated (UTC) in NASA Parallel Binary-4 (PB-4) format, with the parity bits set to logical 0.

### 10.4.4 Data Field

A 4624-bit field that contains the user data. If the user data is less than 4624 bits, fill bits are inserted after the real data.

### 10.4.5 Block Error Control Field

A 32-bit field that enables error detection, as described below:

**a. Bits 4769-4776 (Spares)**

The sender inserts logical 0 bits in this 8-bit field.

**b. Bit 4777 (Polynomial Status Flag)**

A 1-bit field that indicates whether the block passed (logical 0) or failed (logical 1) the sender's polynomial check.

**c. Bit 4778 (Polynomial Status Flag)**

A 1-bit field that indicates whether the block passed (logical 0) or failed (logical 1) the destination system's polynomial check.

**d. Bits 4779-4800 (Polynomial Remainder)**

The sender generates this 22-bit polynomial code.

## 10.5 Mail Delivery of Recorded Data

When the telecommunication circuits at a GN station cannot support the electronic transfer of high-rate science data (X-band or S-band), the GN station will record the science data on magnetic, non-volatile media such as tape or disk. The station will then mail the recorded data to the user.

Operations agreements and support plans define the exact data-shipping criteria. *Table 10-2* identifies the recording capabilities at each GN station; an "X" means that capability is available. *Table 10-3* lists the capabilities of each digital tape recorder.

**Table 10-2.** ***GN Recording Capabilities***

| Station | Magnetic Disk Recording | Magnetic Tape Recording | | | | |
|---|---|---|---|---|---|---|
| | | Ampex DIS260I | Ampex DCSRi 170 | Metrum VLDS | Sony | Analog Recorders |
| SGS | | X | | X | | |
| WGS | | | | X | X | |
| LEO-T – WFF | X | | | | | |
| TOTS – WFF | | | | X | | |
| MGTAS | | | | X | | X |
| SATAN | | | | | | X |
| METEOSAT | X | | | | | |
| Radar Systems | X | | | | | X |
| MGS | | | X | X | | |
| LEO-T – Alaska | X | | | | | |
| TOTS – Alaska | | | | X | | |
| AGS | | X | | X | | |
| MILA | | | | X | | |
| PDL | | | | X | | |

**Table 10-3.** ***Digital Tape Recorder Capabilities***

| Tape Recorder | Tape Format | Maximum Recording Speed | Playback Speed | Tape Storage Capacity |
|---|---|---|---|---|
| Ampex DIS260I | D2 | 160 Mbps | Any | 160 GB |
| Ampex DCSRi 170 | D2 | 105 Mbps | Any | 160 GB |
| Metrum VLDS | S-VHS | 32 Mbps | Any | 10 GB |
| Sony | D2 | 160 Mbps | Any | 160 GB |

## 10.6 Standard Autonomous File Server

This section describes the Standard Autonomous File Server (SAFS). SAFS provides automated management of large data files without interfering with the assets involved in the acquisition of data. SAFS operates as a stand-alone solution, monitoring itself, and providing an automated level of fail-over processing to enhance reliability. By using an improved automated file transfer process, the SAFS system provides a quicker, more reliable file distribution for customers of near real-time data than has been realized by previous methods. Web reporting provides current status of system availability, file latency, and customer file distribution.

### 10.6.1 SAFS Architecture and Operation

Initially, the SAFS was installed at some NASA GN sites for distributed acquisition of satellite data in support of QuikSCAT and ADEOS II missions. The SAFS has been installed at the following GN ground stations: SGS, AGS, WGS, and MGS. It has also been installed at GSFC to provide for centralized customer data distribution. Figure 10-3 depicts the SAFS configuration. The central SAFS provides a single point of contact for customers and isolates the GN ground stations from customer interactions. At each ground station, the telemetry processors accept raw downlinked satellite data and process the data into files (format for later customer consumption) that are sent to the ground station's SAFS via a standard network protocol. The ground station SAFS uses FASTCopy to automatically push the files to the central SAFS via a standard network protocol where the files are made available to each project's customers.

Customers can "pull" a file from the SAFS system once they receive a data ready notification (DRN) of its availability. Or if they are also using FASTCopy, the SAFS system can automatically "push" their files to them which would eliminate the delay inherent in the notification and reaction processes required for "pull" customers.

### 10.6.2 SAFS Hardware and Software

The SAFS system hardware is installed in a standard 19" rack and includes the following:

a. Redundant Array of Independent Disks (RAID) storage system
b. RAID monitoring/configuration system
c. SAFS server
d. Rack mounted keyboard, monitor, and touch pad

The SAFS software includes the following:

a. COTS FASTCopy file transmission software
b. Custom scripts for job control and monitoring
c. Web reporting software

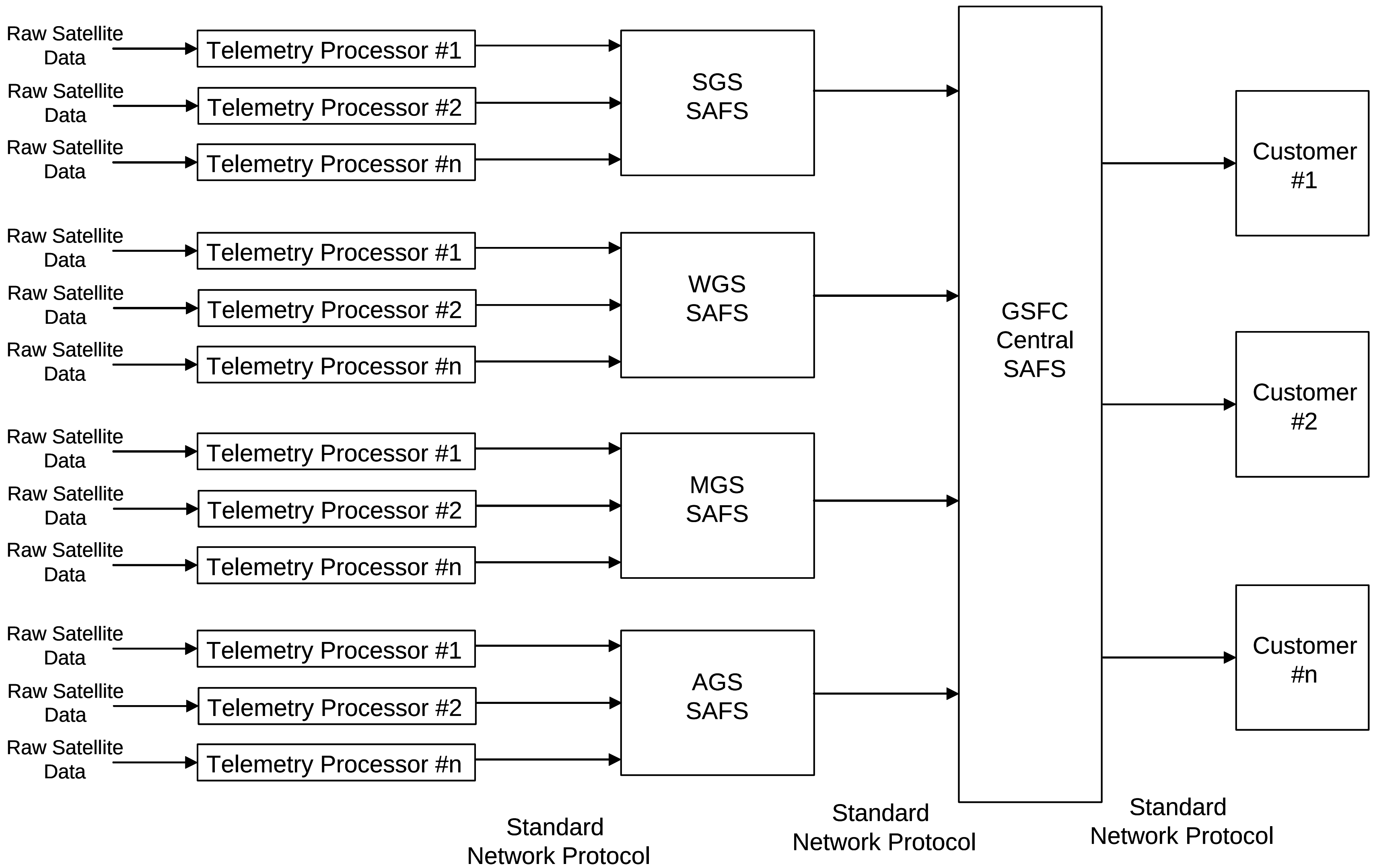


**Figure 10-3. SAFS Architecture**

# Section 11. Frequency Management

## 11.1 Introduction

This section provides information to assist a flight project in determining its frequency spectrum requirements. It also describes the procedures for obtaining authorization for the required spectrum.

## 11.2 Determining Frequency Spectrum Requirements

### 11.2.1 International Spectrum Allocations

International frequency spectrum allocations are prepared by World Radiocommunication Conferences (WRCs) convened under the auspices of the International Telecommunications Union (ITU). These allocations become part of the ITU International Radio Regulations, a treaty that requires ratification by the United States (US).

*Table 11-1* identifies the bands in which the GN is “primary” with respect to other services. Within these bands, GN operations are protected from unacceptable interference from other services.

**Table 11-1*. GN Primary Frequency Allocations***

| Band | Direction | Frequencies |
|---|---|---|
| S-band | Earth-to-space | 2025 – 2110 MHz |
| S-band | Space-to-earth | 2200 – 2290 MHz |
| X-band | Space-to-earth | 8025 – 8400 MHz |

*Table 11-2* and *Table 11-3* list the ITU worldwide S- and X-band frequency allocations, respectively. They also identify the allocations for the NASA Deep Space Network (DSN) in the 2110 - 2120 MHz, 2290 – 2300 MHz, and 8400 – 8500 MHz bands. GN stations must control unwanted emissions in these DSN bands (see Section 11.2.3).

### 11.2.2 US Spectrum Allocations

Management of the radio frequency spectrum within the US is divided between government and non-government uses: the National Telecommunications and Information Agency (NTIA) administers government allocations (including NASA), and the Federal Communications Commission (FCC) manages non-government allocations.

**Table 11-2.** ***S-Band International Frequency Allocations***

| Frequency (MHz) | Service Allocation |
|---|---|
| 2025 – 2110 | SPACE OPERATION (earth-to-space and space-to-space)<br>EARTH EXPLORATION-SATELLITE (earth-to-space and space-to-space)<br>FIXED<br>MOBILE<br>SPACE RESEARCH (earth-to-space and space-to-space) |
| 2110 – 2120 | FIXED<br>MOBILE<br>SPACE RESEARCH (DSN) (earth-to-space) |
| 2200 – 2290 | SPACE OPERATION (space-to-earth and space-to-space)<br>EARTH EXPLORATION-SATELLITE (space-to-earth and space-to-space)<br>FIXED<br>MOBILE<br>SPACE RESEARCH (space-to-earth and space-to-space) |
| 2290 – 2300 | FIXED<br>MOBILE<br>SPACE RESEARCH (DSN) (space-to-earth) |

Note: Uppercase letters indicate *primary* allocations.

NASA is a member of the NTIA's Interdepartment Radio Advisory Committee (IRAC), which coordinates US spectrum allocation issues. US allocations relevant to the GN are identical to the international allocations listed in Table 11-2 and Table 11-3.

### 11.2.3 DSN Protection

As stated above, the DSN has primary allocations in the 2110 – 2120 MHz, 2290 – 2300 MHz, and 8400 – 8500 MHz bands. Each of these bands is adjacent to a GN allocation. GN operators are responsible for protecting DSN stations from unacceptable interference.

ITU limits on power-flux density in the DSN band from non-DSN transmitters are summarized in *Table 11-4*.

**Table 11-3.** ***X-Band International Frequency Allocations***

| Frequency (MHz) | Service Allocation |
|---|---|
| 7075 – 7250 | FIXED<br>MOBILE |
| 8025 – 8175 | EARTH EXPLORATION-SATELLITE (space-to-earth)<br>FIXED<br>FIXED-SATELLITE (earth-to-space)<br>MOBILE |
| 8175 – 8215 | EARTH EXPLORATION-SATELLITE (space-to-earth)<br>FIXED<br>FIXED-SATELLITE (earth-to-space)<br>METEOROLOGICAL-SATELLITE (earth-to-space)<br>MOBILE |
| 8215 – 8400 | EARTH EXPLORATION-SATELLITE (space-to-earth)<br>FIXED<br>FIXED-SATELLITE (earth-to-space)<br>MOBILE |
| 8400 – 8500 | FIXED<br>MOBILE<br>SPACE RESEARCH (DSN) (space-to-earth) |

Note: Uppercase letters indicate *primary* allocations.

### 11.2.4 In-Band Power-Flux Density Restrictions

GN users share the 2200 – 2290 MHz and 8025 – 8400 MHz receive bands with terrestrial services. Terrestrial services are protected by limiting the power-flux density at the surface of the earth from space-based transmitters; *Table 11-5* summarizes these limits.

**Table 11-4.** ***Interference Protection Requirements for DSN***

| Frequency (MHz) | Maximum Allowable Interference Spectral Power-Flux Density at Aperture of DSN Antenna ($dBW/m^2$ Hz) |
|---|---|
| 2290 – 2300 | -257.0 |
| 8400 – 8450 | -255.1 |

Source: ITU Recommendation ITU-R SA.1273

**Table 11-5.** ***In-Band Protection Requirements for Terrestrial Services***

| Frequency (MHz) | Power-Flux Density Limit for Angles of Arrival (q) Above the Horizontal Plane ($dBW/m^2$) | | | Reference Bandwidth |
|---|---|---|---|---|
| | **0°** £ q £ **5°** | **5°** < q < **25°** | **25°** £ q £ **90°** | |
| 2025 – 2110 | -154 | -154 + 0.5 (θ - 5) | -144 | 4 kHz |
| 2200 – 2290 | -130 | -130 + 0.5 (θ - 5) | -120 | 1 MHz |
| 8025 – 8400 | -150 | -150 + 0.5 (θ - 5) | -140 | 4 kHz |

Sources: ITU Recommendation ITU-R SA.1273
International Radio Regulations: Article S21 (Table S21-4)

## 11.3 Obtaining Frequency Spectrum Authorization

### 11.3.1 Regulations, Policies, and Instructions

NASA missions must comply with all US and international frequency spectrum requirements. Reference [l] in Section 1.3 states these requirements and other legal obligations mandated by NTIA. Reference [n] provides detailed instructions for obtaining frequency spectrum authorization in compliance with Reference [o].

### 11.3.2 GSFC Spectrum Management Office

The GSFC Spectrum Management Office is responsible for all spectrum-related activities associated with the GN. The Office is part of the Mission Services Program Office, Code 450.0. The responsibilities of the Spectrum Management Office include:

1. Coordinate RF spectrum requirements pertaining to GSFC and GN resources, in accordance with Chapter 3 of Reference [o] in Section 1.3.
2. Ensure interference-free operations between user vehicles and the GN, in accordance with Chapter 4 of Reference [o].
3. Assist the flight project in determining frequency requirements, including performing interference analyses.
4. Provide guidance in completing the Frequency Authorization Request Package to be sent to the NTIA. Chapter 10 of Reference [p] provides instructions for filling out the forms in the Package.
5. Coordinate with the NTIA's Space Systems Group, which conducts the frequency spectrum allocation review. Appendix G of Reference [o] describes the four-stage review process.

### 11.3.3 Flight Project Responsibilities

Flight projects that would like to use the GN should contact the GSFC Spectrum Management Office to begin the allocation request process as soon as possible (see Section 11.3.2 above). Each project must designate a point-of-contact for working with the Spectrum Management Office.

## 11.4 Space Frequency Coordination Group Recommendations

In order to more efficiently utilize the limited spectrum allocated for space-to-Earth data transmissions, the Space Frequency Coordination Group (SFCG) has recommended that space projects starting after the year 2001 comply with an emitted spectrum mask for space-to-Earth data transmissions in the bands 2200-2300 MHz and 8025-8500 MHz (SFCG Recommendation 17-2R1). Figure 11-1 depicts the SFCG 17-2R1 mask recommendation for suppressed carrier modulation systems with data rates greater than or equal to 2 Mbps. See reference [w] for additional information on the SFCG recommendations.

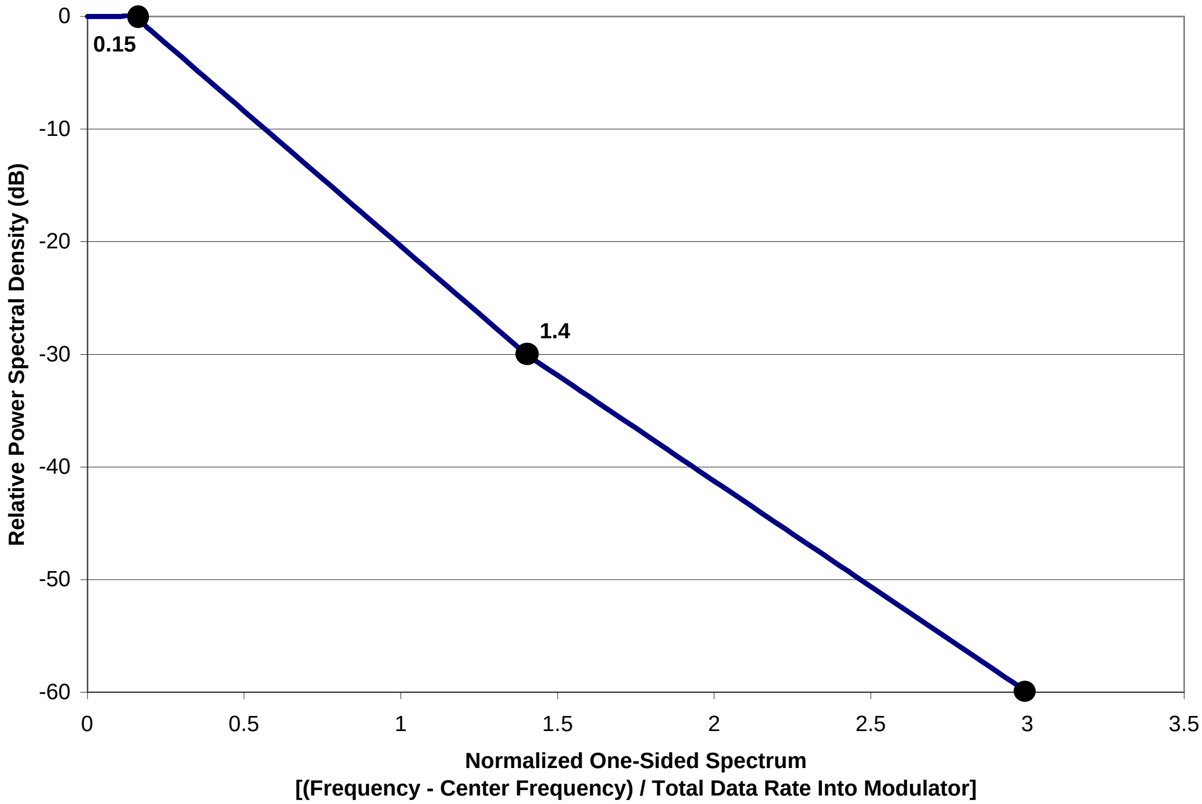


**Figure 11-1. SFCG Spectral Limit Recommendation**

# Section 12.  Link Budget Parameters

This section provides S-band and X-band link parameters that will assist flight projects with link budget calculations. The link budget parameters provided in this section are estimated values for example purposes only. For specific link budget calculations, contact the Mission Services Program Office. This section provides the following information:

- S-band atmospheric and rain attenuation constants.
- X-band atmospheric and rain attenuation constants.
- Example user spacecraft constraint losses and ground terminal losses for telemetry links.
- X-band G/T measurement data.
- Ground station line-of-sight coverage for spacecraft altitudes between 500 km and 1000 km.

## 12.1  S-band Atmospheric and Rain Attenuation Constants

Atmospheric and rain attenuation constants were developed for S-band (2200 MHz - 2300 MHz) GN stations using ITU models. For the GN stations listed in this document, the S-band atmospheric attenuation constant at a 5° elevation angle is 0.41 dB. The atmospheric attenuation constant includes scintillation effects.

*Table 12-1* lists the S-band rain attenuation constants for the GN stations that have S-band capabilities.

## 12.2  X-band Atmospheric and Rain Attenuation Constants

Atmospheric and rain attenuation constants were developed for the X-band (8000 MHz - 8500 MHz) GN stations using ITU models. For the GN stations listed in this document, the X-band atmospheric attenuation constant at a 5° elevation angle is 0.5 dB. The atmospheric attenuation constant includes scintillation effects.

*Table 12-2* lists the X-band rain attenuation constants for the GN stations that have X-band capabilities.

## 12.3  Implementation Losses, Constraint Losses, and Ground Terminal Losses

Constraint loss is the link degradation due to linear and non-linear spacecraft transmitter distortions. Ground terminal loss is the link degradation due to ground terminal receive system distortions. The sum of the constraint loss and the ground terminal loss is typically stated as the implementation loss in GN link budgets.

Constraint losses and ground terminal losses vary with spacecraft and ground station design, and are usually analyzed on a case-by-case basis. There is no fixed constraint loss value for all spacecraft and no fixed ground terminal loss value for all GN stations. Variations in a spacecraft's transmitter signal characteristics from mission to mission can significantly impact the amount of constraint loss. Likewise, variations in the ground terminal's receive performance characteristics and operational data rate can significantly impact the amount of ground terminal loss. The Mission Services Program Office typically performs analytical modeling and simulation as required for specific flight project communications hardware and GN receivers to estimate the overall implementation loss for a mission link budget.

Paragraphs 12.3.1 and 12.3.2 provide example implementation losses, constraint losses, ground terminal losses, and distortion characteristics for X-band and S-band links, respectively.

The loss values and parameters discussed below in paragraphs 12.3.1 and 12.3.2 are intended to only provide the user an example of the expected link performances under specific scenarios. As previously stated, implementation loss for GN links should be analyzed on a case-by-case basis. The implementation loss assessment will determine the additional user spacecraft EIRP required to provide acceptable performance throughout the lifetime of the mission.

In addition to the distortion characteristics stated in paragraphs 12.3.1 and 12.3.2, the Consultative Committee for Space Data Systems (CCSDS) and Space Frequency Coordination Group (SFCG) provide recommended X-band and S-band spacecraft characteristics and distortion limits for space-to-Earth data transmissions. This information can be found in references [w].

### 12.3.1 X-Band Implementation Loss Examples

*Table 12-3* lists the signal characteristics specified for the ICESat X-band transmitter. Simulation for the ICESat project resulted in an estimated constraint loss of 3.0 dB. The constraint loss is greatly dependent on the shape of the transmitter signal magnitude and phase response over the 3 dB bandwidth. Because the actual (measured) response was not available for the simulation, a response shape was assumed for the simulation. As test data becomes available for the flight hardware, the simulations can be repeated using measured distortion values to improve the accuracy of the constraint loss estimate.

The ground terminal loss for ICESat was estimated by performing characterization tests at the Wallops Ground Station using similar (but not identical) equipment that will be implemented for ICESat (reference [u]). The test results indicated an estimated ground terminal loss of 2.0 dB. Thus, the resulting X-band implementation loss for the ICESat link budget was estimated at 5.0 dB.

Similar analyses for the PM-1 mission resulted in an estimated spacecraft constraint loss of 1.9 dB and a ground terminal loss of 2.5 dB for a total implementation loss of 4.4 dB. The difference in implementation loss between PM-1 and ICESat can be attributed to a number of factors including required BER (10E-3 for PM-1 versus 10E-5 for ICESat), the use of measured transmitter gain flatness and phase non-linearity values rather than specified values, and differences in other signal parameters such as data rate, phase noise, and AM/PM distortion.

### 12.3.2 S-Band Implementation Loss Examples

*Table 12-4* lists the signal characteristics for a typical LEO spacecraft's S-Band transmitter for the following two scenarios:

(1) Suppressed carrier modulation, but no convolutional coding

(2) Phase Modulation (PM) with a residual carrier, but no convolution coding.

*Table 12-5* lists the signal characteristics for a typical LEO spacecraft's S-Band transmitter for the following two scenarios:

(1) Suppressed carrier modulation with rate ½ convolutional coding

(2) PM with a residual carrier with rate ½ convolution coding

Simulations were conducted to determine the implementation loss for S-Band using suppressed carrier modulation schemes and PM with a residual carrier. The simulations were conducted with and without rate ½ convolution. Ground station characteristics were included in the simulations. The ground station characteristics were assumed, but the fidelity scenarios assumed were a conservative representation for existing (or future) GN ground terminals.

Simulations using the Table 12-4 and Table 12-5 characteristics yielded the implementation losses listed in *Table 12-6*:

As an example of implementation loss for S-Band links with subcarriers, reference [v] states an implementation loss for the ICESat S-band subcarrier telemetry link (PCM, BPSK, PM) as 2.0 dB.

## 12.4 X-band G/T Measurement Data

*Table 12-7* lists the SGS X-band G/T data which was measured during tests performed in August 1998.

Actual G/T measurement data is not available for other GN ground stations, however, as it becomes available, this document will be updated.

## 12.5 Ground Station Line-Of-Sight Coverage

Figures 12-1 through 12-15 depict each ground station's line-of-sight coverage for spacecraft altitudes of 500 km, 750 km, and 1000 km. All line-of-sight coverages are based on the local terrain, except for Figures 12-3, 12-5, and 12-10, which use a uniform 5º mask. Line-of-sight coverage analyses for specific mission orbit parameters can be performed by the Mission Services Program Office.

**Table 12-1.** ***S-Band Rain Attenuation Constants (5° elevation angle)***

| Ground Station | Rain Attenuation for 99% Availability (dB) | Rain Attenuation for 99.9% Availability (dB) |
|---|---|---|
| SGS (Norway) | 0.0 | 0.0 |
| WGS (WFF) | 0.01 | 0.06 |
| LEO-T (WFF) | 0.01 | 0.06 |
| TOTS (WFF) | 0.01 | 0.06 |
| MGTAS (WFF) | 0.01 | 0.06 |
| SATAN (WFF) | 0.01 | 0.06 |
| SCAMP (WFF) | 0.01 | 0.06 |
| METEOSAT (WFF) | 0.01 | 0.06 |
| MGS (Antarctica) | 0.0 | 0.0 |
| LEO-T (Alaska) | 0.0 | 0.01 |
| TOTS (Alaska) | 0.0 | 0.01 |
| AGS (Alaska) | 0.0 | 0.01 |
| MILA (Florida) | 0.05 | 0.23 |
| PDL (Florida) | 0.04 | 0.16 |

**Table 12-2.** ***X-Band Rain Attenuation Constants (5° elevation angle)***

| Ground Station | Rain Attenuation for 99% Availability (dB) | Rain Attenuation for 99.9% Availability (dB) |
|---|---|---|
| SGS (Norway) | 0.0 | 0.11 |
| WGS (WFF) | 0.34 | 3.52 |
| MGS (Antarctica) | 0.0 | 0.76 |
| AGS (Alaska) | 0.0 | 0.24 |

**Table 12-3. *ICESat X-Band Transmitter Characteristics***

| Parameter | Value |
|---|---|
| Frequency | 8100 MHz |
| Data Format | NRZ-M |
| Data Rate (I/Q Bit Rate) | 20 Mbps on each channel (40 Mbps total) |
| Data Modulation | Staggered QPSK |
| Data Asymmetry (1) | ≤ 3 percent |
| Data Rise Time (1) | ≤ 2.5 nsec |
| Data Bit Jitter (1) | ≤ 1 percent |
| I/Q Power Ratio | 1:1 |
| I/Q Data Skew (1) | 0.5 ± 0.1 symbol period |
| QPSK Gain Imbalance | ≤ 1.2 dB peak to peak |
| QPSK Phase Imbalance | ≤ 5.0 degrees |
| AM/AM | ≤ 1.0 dB/dB |
| AM/PM | ≤ 10.0 degrees/dB |
| 3 dB Bandwidth | 60.0 MHz |
| Roll-off | 0.62 dB/MHz |
| Gain Flatness | ≤ 2.0 dB peak to peak |
| Gain Slope | ≤ 0.4 dB/MHz |
| Phase Nonlinearity | ≤ 5.0 dB peak to peak |
| Phase Noise (1)<br>100 Hz – 40 MHz offset from carrier | ≤ 2.0 degrees RMS |
| Spurious Phase Modulation (1) | ≤ 2.0 degrees RMS |
| Out-of-Band Spurious Output (1) | ≤ -40 dBc |
| Incidental AM (1) | ≤ 5 percent |

(1) Parameter not simulated for ICESat constraint loss estimate

**Table 12-4.** ***USAT S-Band Transmitter Characteristics (Uncoded)***

| Parameter | Value |
|---|---|
| Frequency | 2200-2400 MHz |
| Data Format | NRZ-L |
| Data Rate (I/Q Bit Rate) | 4 Mb/sec (BPSK)<br>8 Mb/sec (QPSK) |
| Data Modulation | BPSK, QPSK |
| Data Asymmetry | 3 percent |
| Data Rise Time | 5 percent |
| Data Bit Jitter (1) | $\leq$ 0.1 percent |
| I/Q Power Ratio | 1:1 |
| I/Q Data Skew | 2.5 percent |
| Gain Imbalance | 0.25 dB |
| Phase Imbalance | 3.0 degrees |
| AM/AM | 0 dB/dB (full saturation) |
| AM/PM | 12 degrees/dB |
| 3 dB Bandwidth | 8.0 MHz |
| Roll-off | 25 dB/MHz |
| Gain Flatness (peak-to-peak) | 0.3 dB over ± 3.5 MHz |
| Gain Slope | 0.1 dB/MHz |
| Phase Nonlinearity (peak-to-peak) | 3.0 degrees over ± 3.5 MHz |
| Phase Noise (1) | 1 Hz – 10 Hz: $\leq$ 50.0 degrees RMS<br>10 Hz – 100 Hz: $\leq$ 6.0 degrees RMS<br>100 Hz – 1 kHz: $\leq$ 2.5 degrees RMS<br>1 kHz – 6 MHz: $\leq$ 2.5 degrees RMS |
| Spurious Phase Modulation | 2 degrees RMS @ 15.63 kHz (BPSK)<br>1 degree RMS @ 15.63 kHz (QPSK) |
| Spurious Outputs | -23 dBc @ 47.0 kHz<br>-15 dBc @ 12.0 MHz |
| Incidental AM | 5 percent @ 7.48 kHz |

(1) Parameter not simulated, but impact on implementation loss determined via analysis techniques

**Table 12-5.** ***USAT S-Band Transmitter Characteristics (rate ½ convolutional coding)***

| Parameter | Value |
|---|---|
| Frequency | 2200 – 2400 MHz |
| Data Format | NRZ-L |
| Data Rate (I/Q Bit Rate) | 2 Mb/sec (BPSK)<br>4 Mb/sec (QPSK) |
| Data Modulation | BPSK, QPSK |
| Data Asymmetry | 3 percent |
| Data Rise Time | 5 percent |
| Data Bit Jitter(1) | 0.1 percent |
| I/Q Power Ratio | 1:1 |
| I/Q Data Skew | 2.5 percent |
| Gain Imbalance | 1.0 dB (BPSK); 0.5 dB (QPSK) |
| Phase Imbalance | 9.0 degrees (BPSK); 5.0 degrees (QPSK) |
| AM/AM | 0 dB/dB (full saturation) |
| AM/PM | 15 degrees/dB |
| 3 dB Bandwidth | 8.0 MHz |
| Roll-off | 25 dB/MHz (BPSK)<br>50 dB/MHz (QPSK) |
| Gain Flatness (peak-to-peak) | 0.4 dB over ± 3.5 MHz |
| Gain Slope | 0.1 dB/MHz |
| Phase Nonlinearity (peak-to-peak) | 4.0 degrees over ± 3.5 MHz |
| Phase Noise (1) | 1 Hz – 10 Hz: ≤ 50.0 degrees RMS<br>10 Hz – 100 Hz: ≤ 6.0 degrees RMS<br>100 Hz – 1 kHz: ≤ 2.5 degrees RMS<br>1 kHz – 6 MHz: ≤ 2.5 degrees RMS |
| Spurious Phase Modulation | 2 degrees RMS @15.6 kHz (BPSK) 1 degree RMS @ 15.6 kHz (QPSK) |
| Spurious Outputs | -23 dBc @ 23.5 kHz<br>-15 dBc @ 12.0 MHz |
| Incidental AM | 5 percent @ 3.74 kHz |

(1) Parameter not simulated, but impact on implementation loss determined via analysis techniques

**Table 12-6.** ***S-Band Implementation Losses***

| Modulation Scheme | Implementation Loss |
|---|---|
| PM, Residual Carrier | 1.7 dB |
| BPSK | 1.7 dB |
| QPSK | 4.2 dB |
| PM, Residual Carrier (rate ½ coding) | 1.9 dB |
| BPSK (rate ½ coding) | 1.9 dB |
| QPSK (rate ½ coding) | 2.3 dB |

**Table 12-7.** ***SGS X-band G/T Measurement Data***

| X-band Channel | Frequency (MHz) | Elevation @ 13° (SUN) | | Elevation @ 56° (Cass-A star) | |
|---|---|---|---|---|---|
| | | RHC (dB/K) | LHC (dB/K) | RHC (dB/K) | LHC (dB/K) |
| 1 | 8140 | 35.9 | 35.8 | 33.7 | 34.8 |
| 2 | 8140 | 34.9 | 34.8 | 32.8 | 33.9 |
| 3 | 8140 | 36.0 | 35.9 | 34.3 | 34.5 |
| 4 | 8140 | 35.9 | 35.9 | 35.1 | 34.7 |
| 1 | 8240 | 36.5 | 36.3 | 35.3 | 35.4 |
| 2 | 8240 | 36.5 | 36.3 | 35.4 | 35.9 |
| 3 | 8240 | 36.4 | 36.3 | 35.2 | 36.3 |
| 4 | 8240 | 36.5 | 36.3 | 35.1 | 35.5 |
| 1 | 8340 | 36.2 | 36.2 | 35.5 | 35.3 |
| 2 | 8340 | 36.2 | 36.2 | 35.5 | 34.8 |
| 3 | 8340 | 36.2 | 36.2 | 34.7 | 33.4 |
| 4 | 8340 | 36.2 | 36.2 | 35.4 | 35.7 |

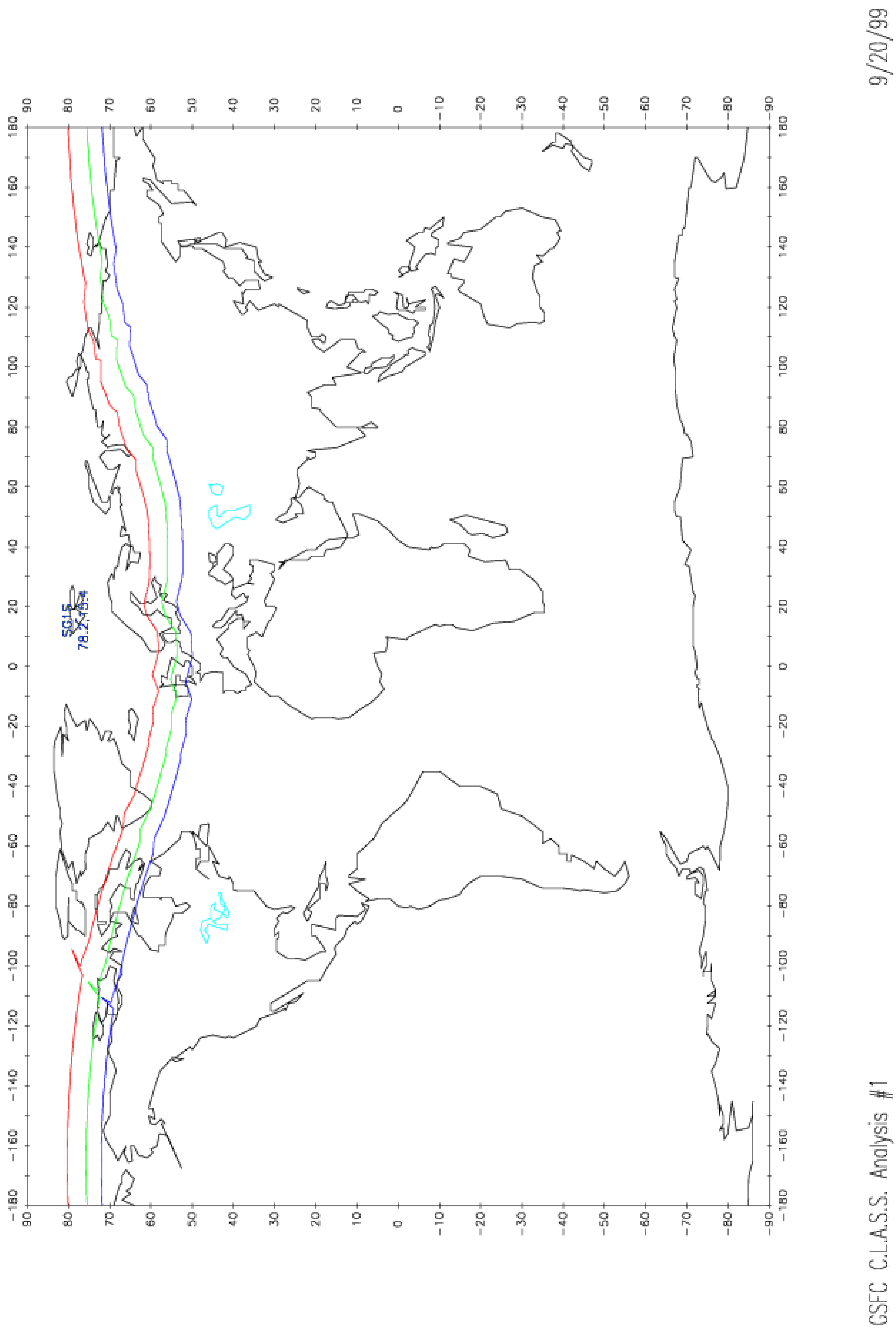


**Figure 12-1. SGS Line-Of-Sight Coverage**

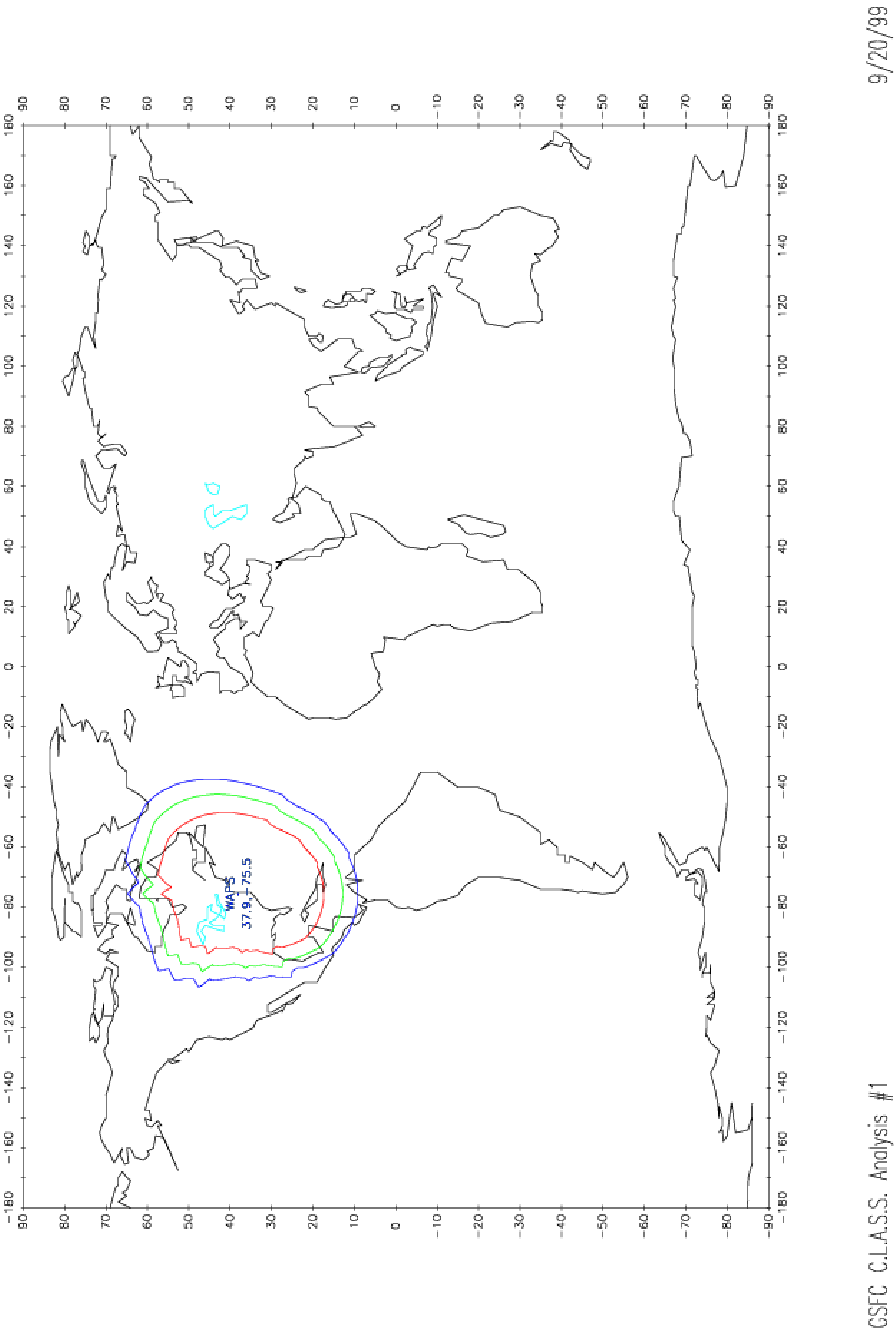


**Figure 12-2. WGS Line-Of-Sight Coverage**

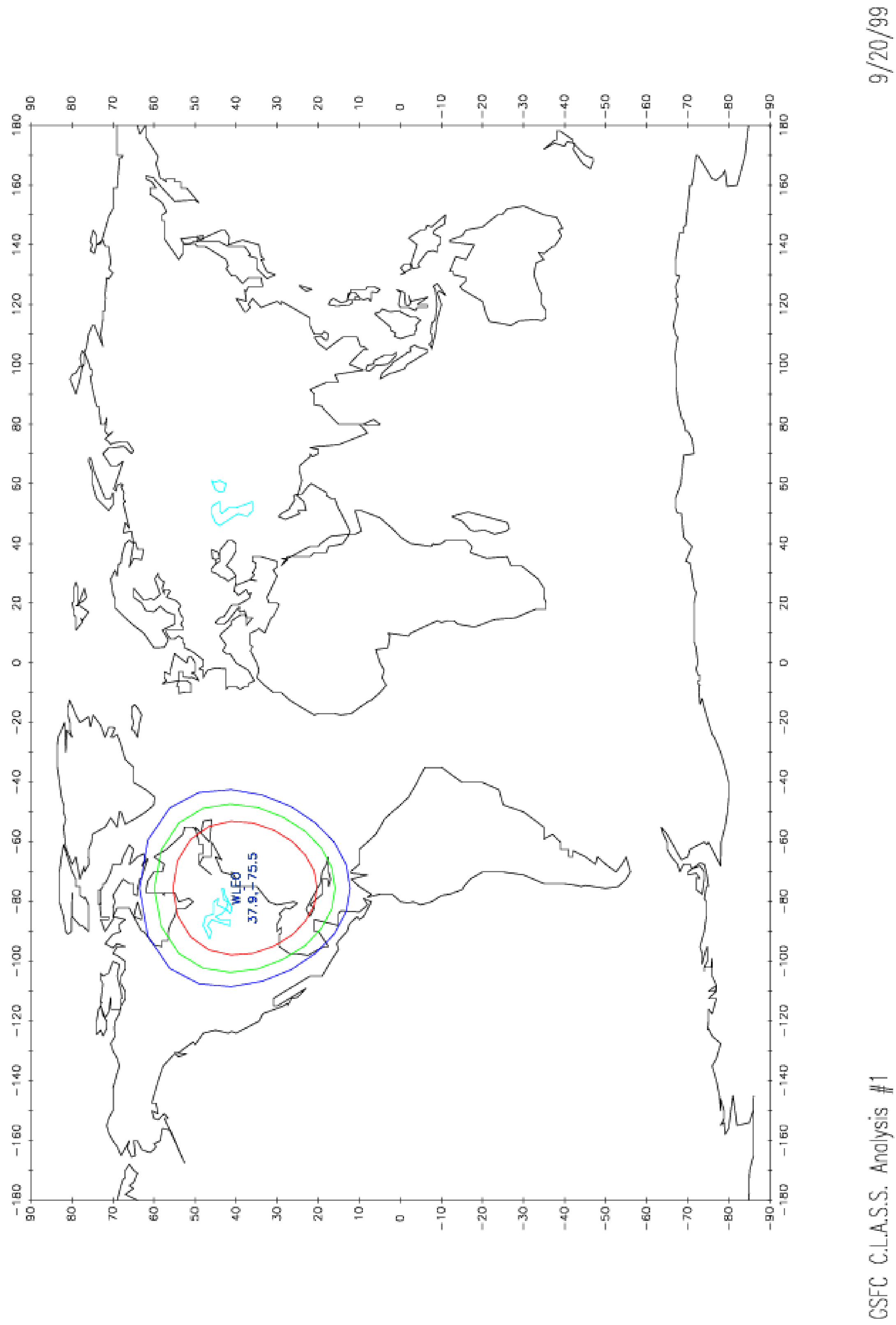


**Figure 12-3. LEO-T (WFF) Line-Of-Sight Coverage**

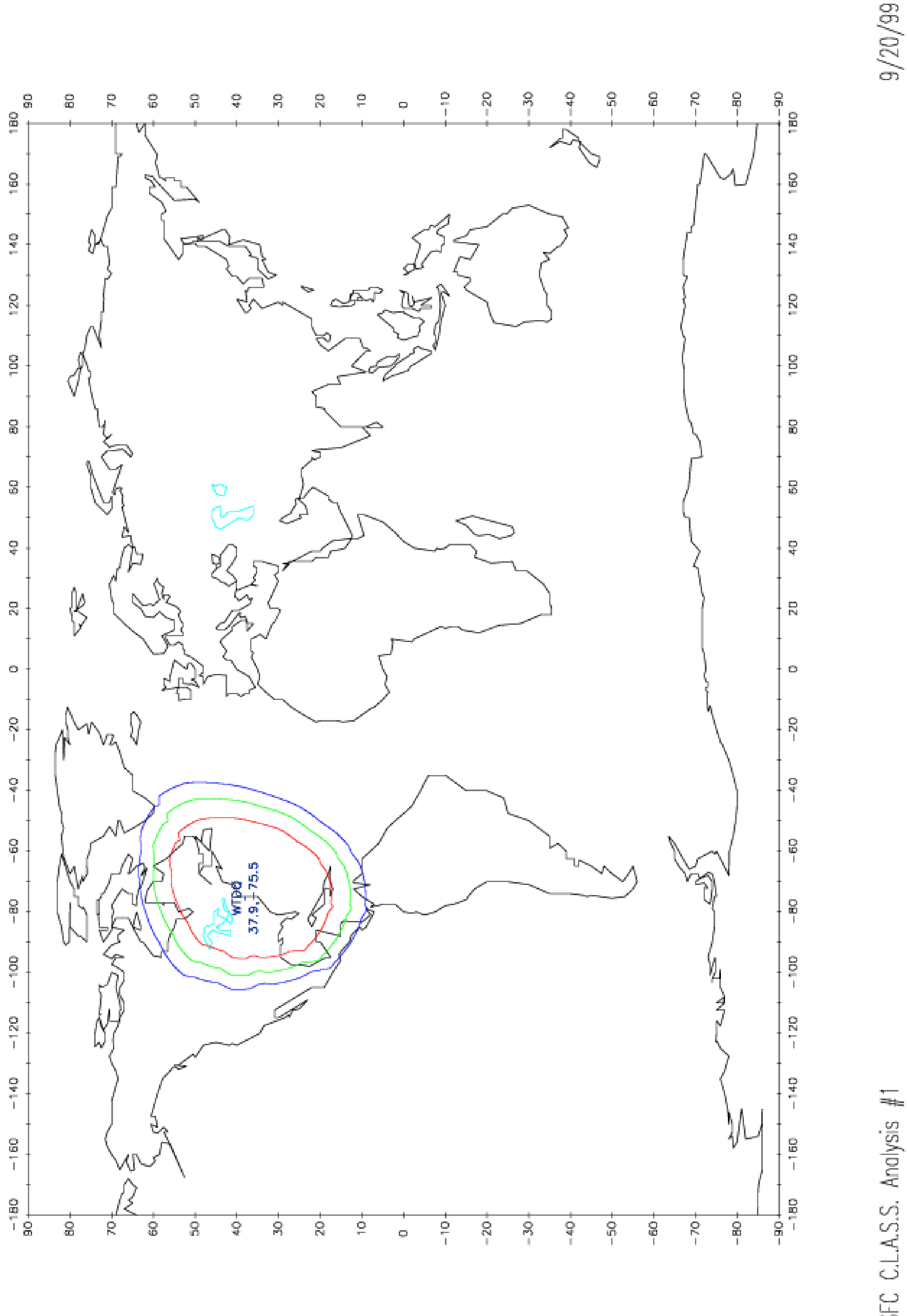


**Figure 12-4. TOTS (WFF) Line-Of-Sight Coverage**

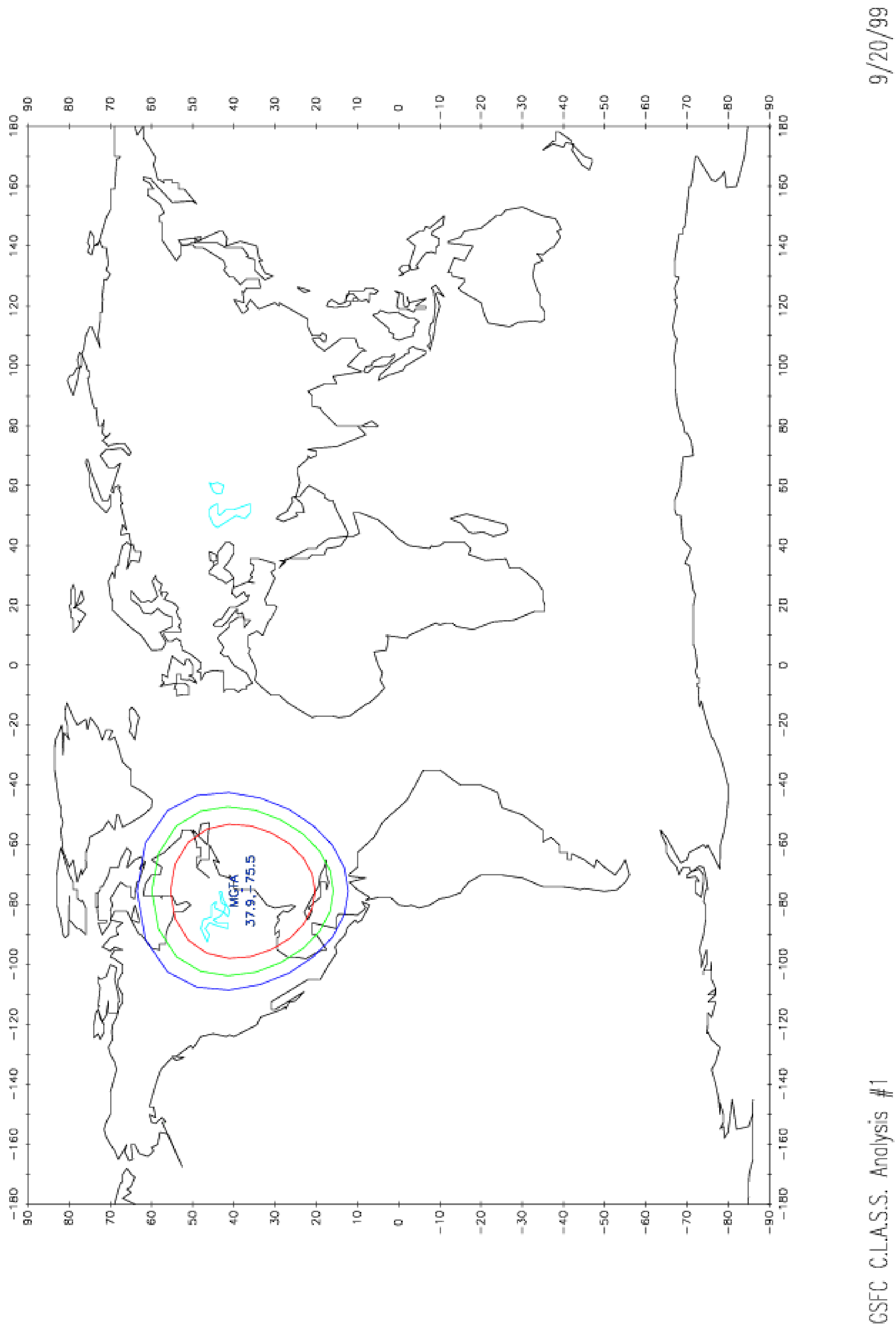


**Figure 12-5. MGTAS Line-Of-Sight Coverage**

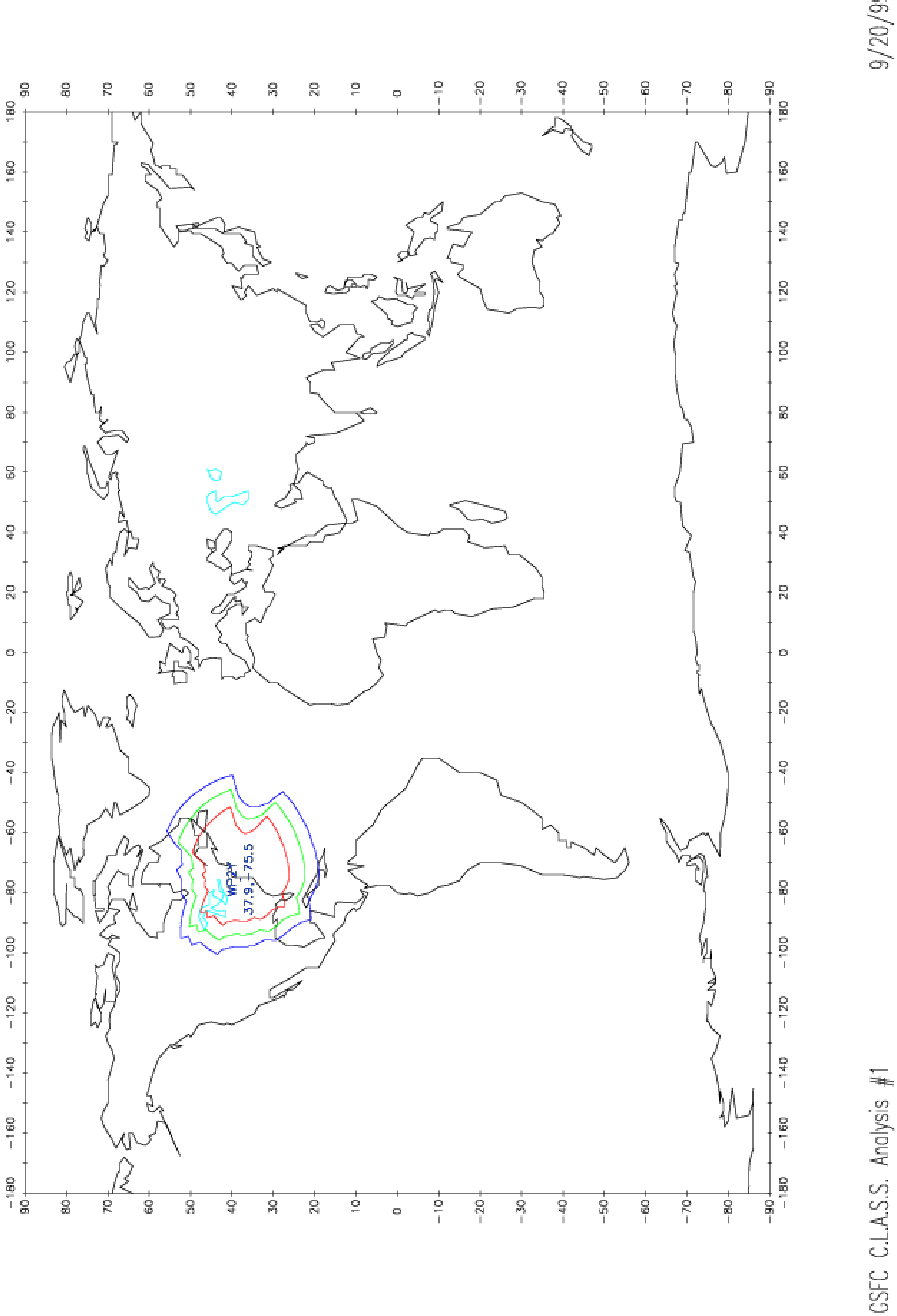


**Figure 12-6. SATAN Line-Of-Sight Coverage**

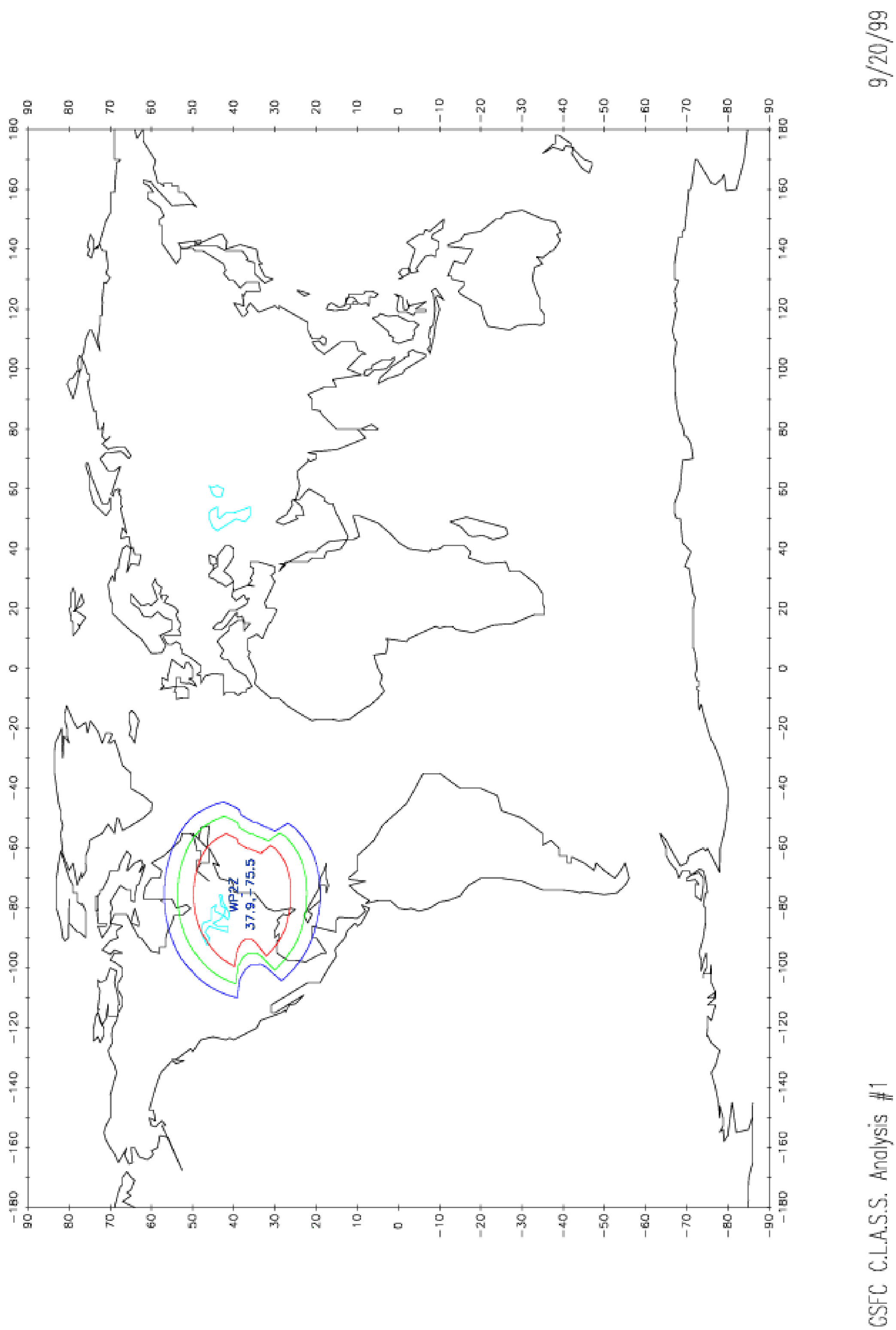


**Figure 12-7. SCAMP Line-Of-Sight Coverage**

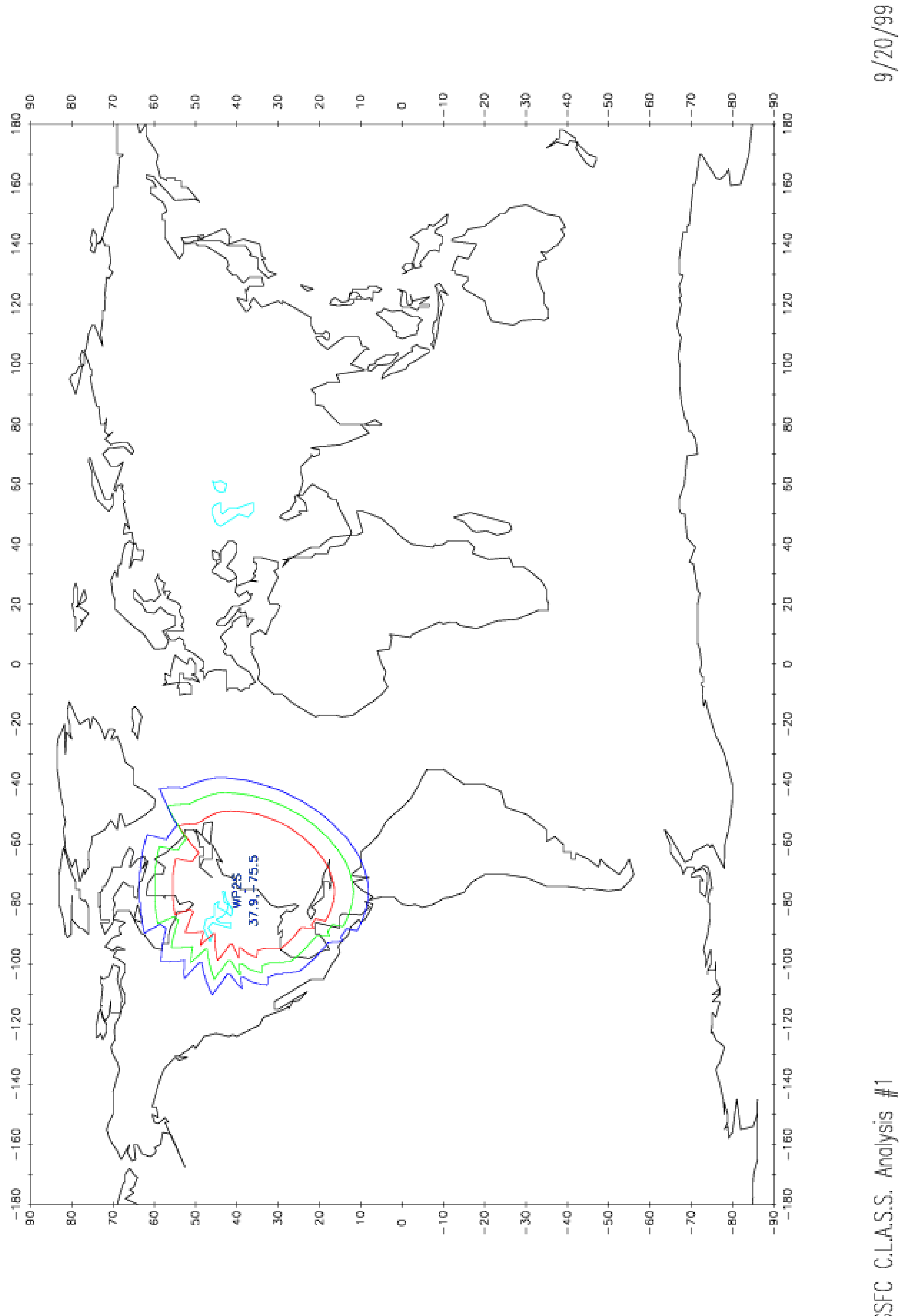


**Figure 12-8. METEOSAT Line-Of-Sight Coverage**

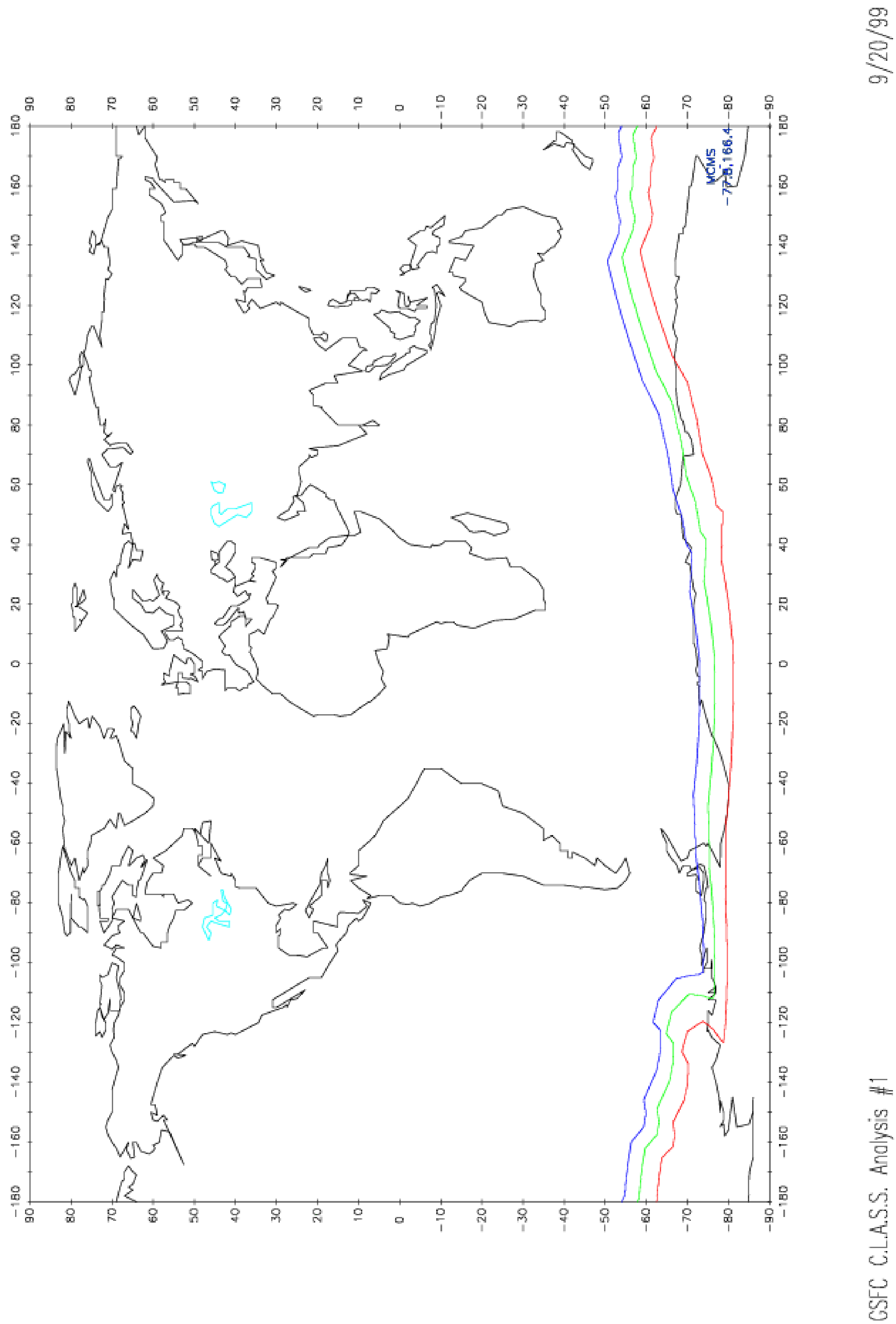


**Figure 12-9. MGS Line-Of-Sight Coverage**

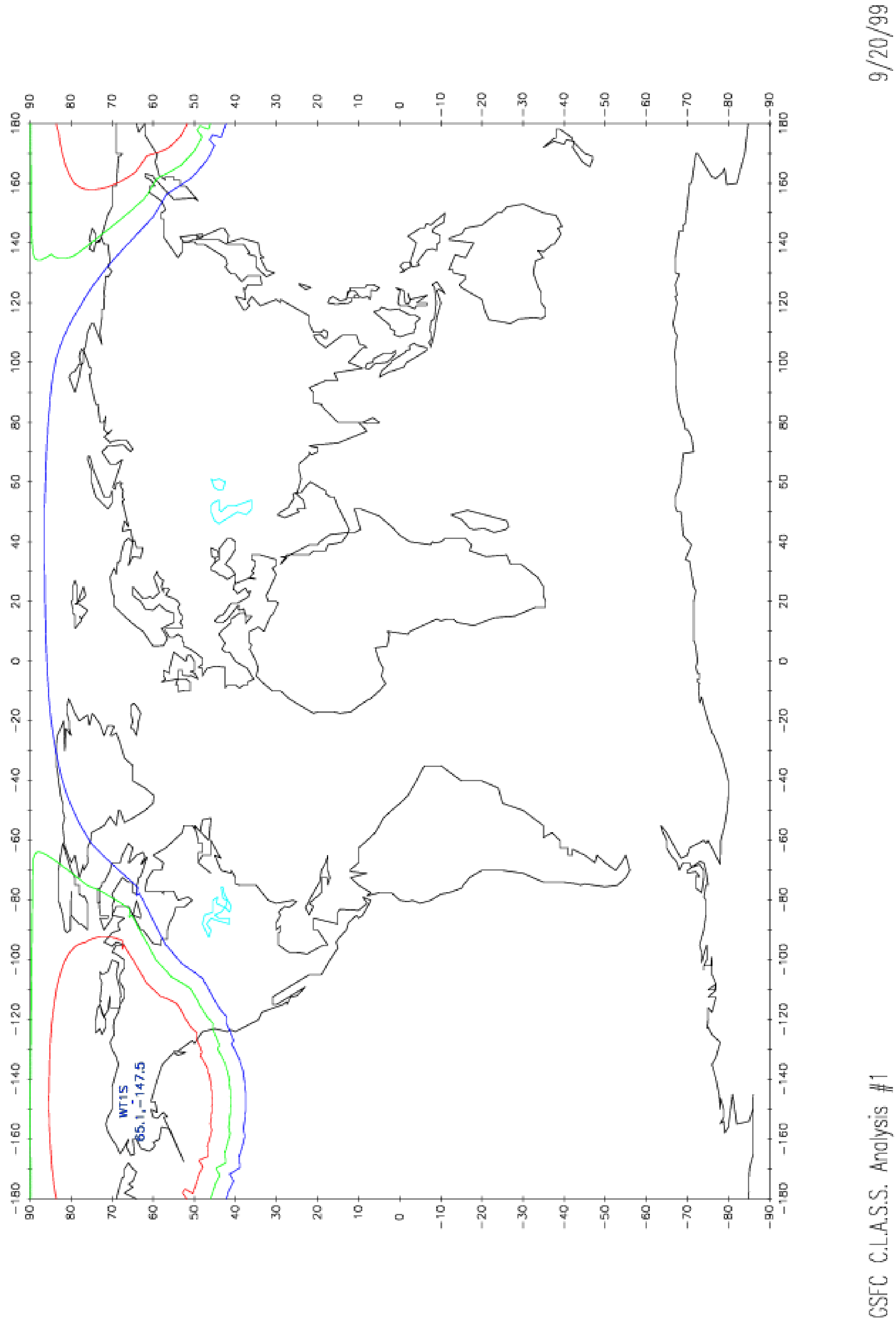


**Figure 12-10. LEO-T (Alaska) Line-Of-Sight Coverage**

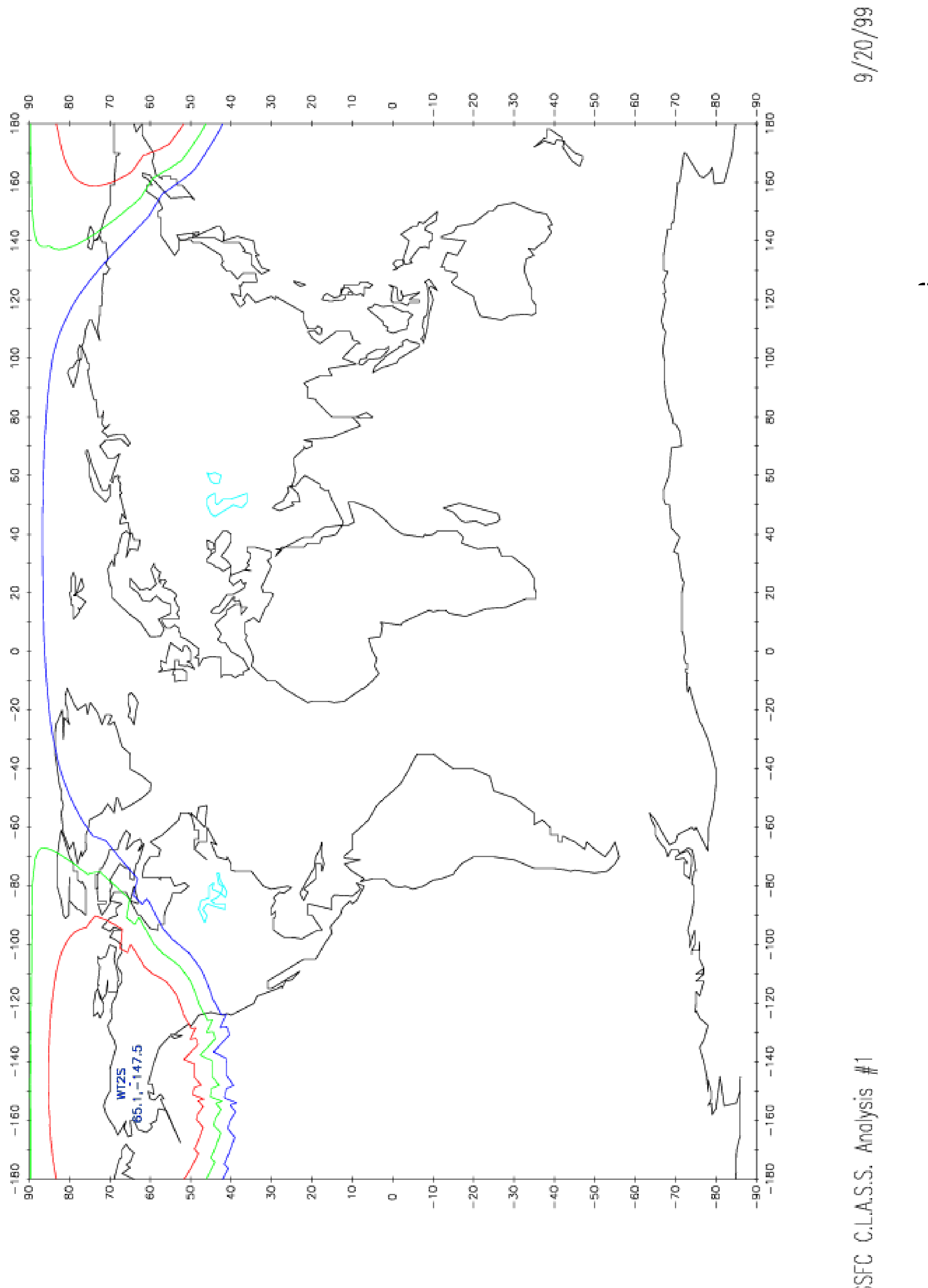


**Figure 12-11. TOTS (Alaska) Line-Of-Sight Coverage**

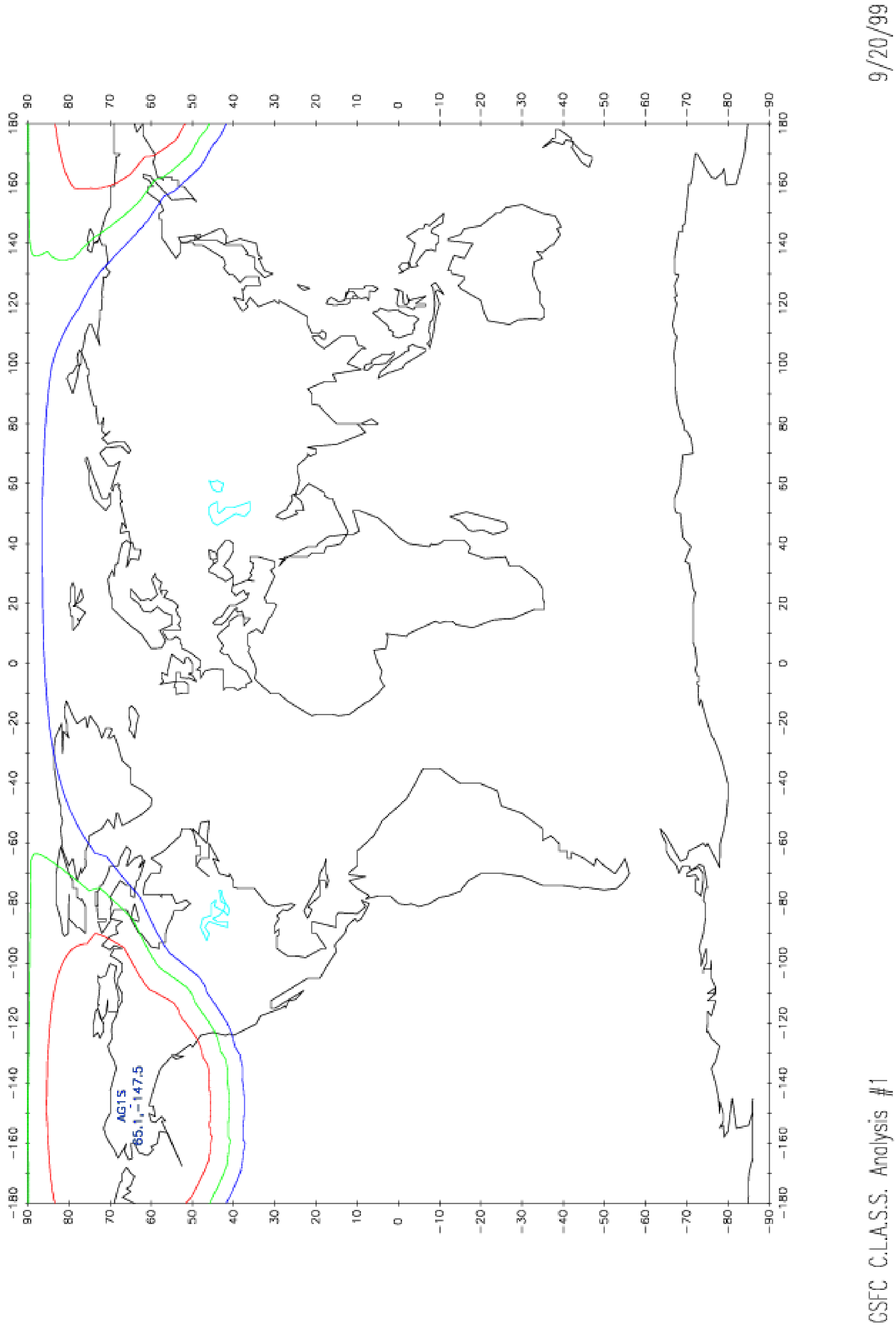


**Figure 12-12. AGS Line-Of-Sight Coverage**

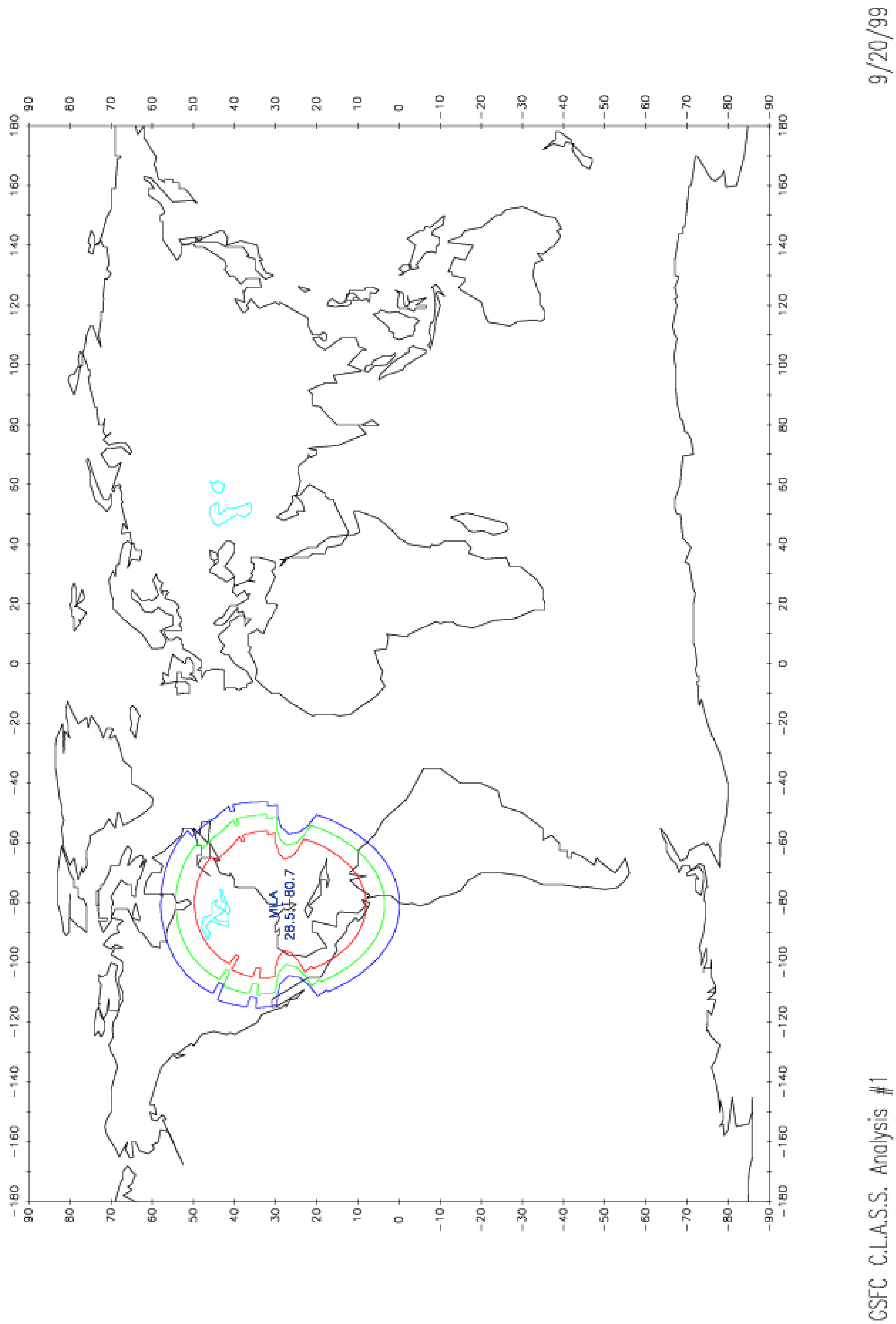


**Figure 12-13. MILA Line-Of-Sight Coverage**

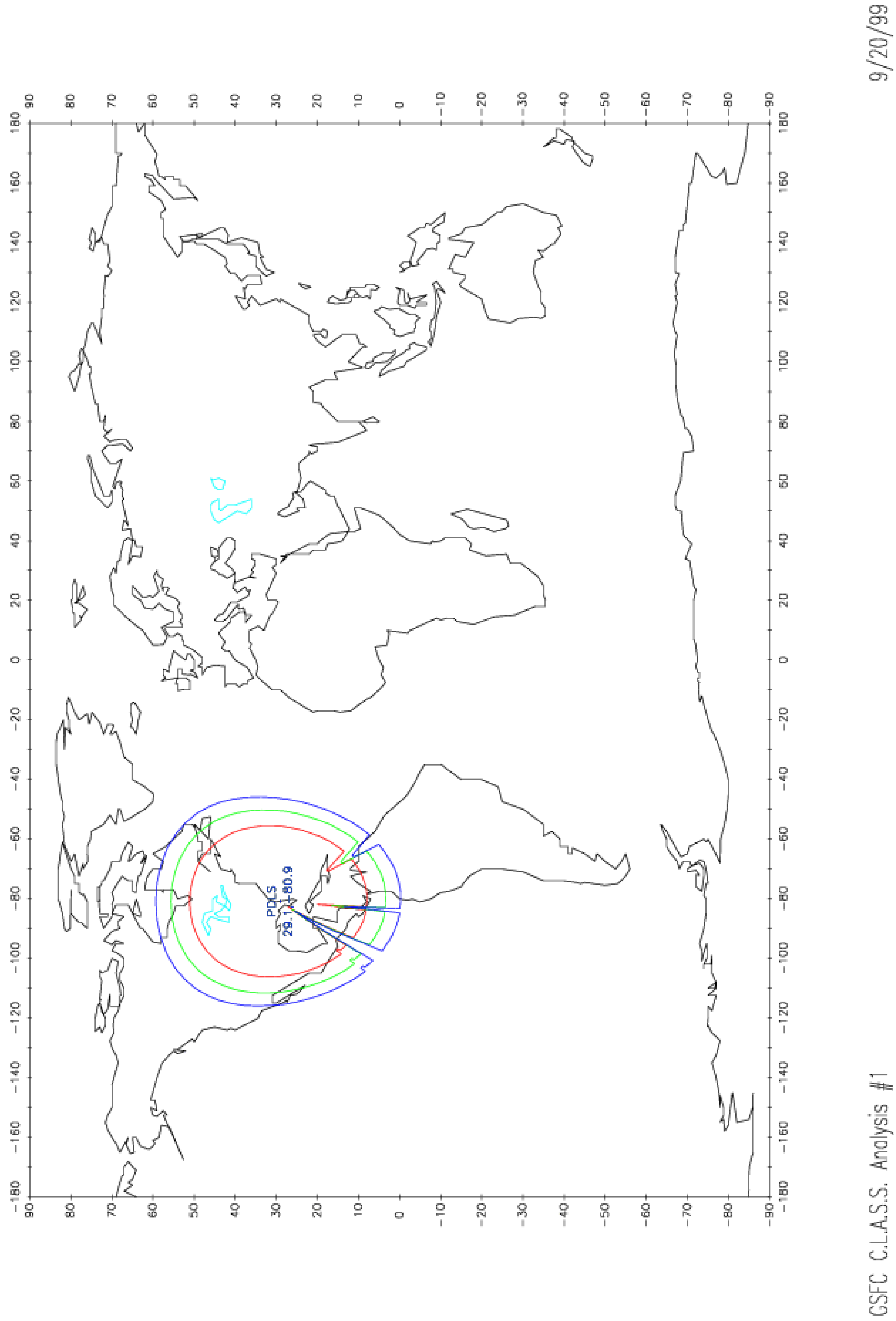


**Figure 12-14.  PDL Line-Of-Sight Coverage**

# Appendix A.  Acronyms

| | |
|---|---|
| ACE | Advanced Composition Explorer |
| AGS | Alaska Ground Station |
| AWOTS | Automated Wallops Orbital Tracking Station Project |
| AXAF | Chandra Advanced X-ray Astrophysics Facility |
| CADU | Channel Access Data Unit |
| CCSDS | Consultative Committee for Space Data Systems |
| CDH | Command Delivery Header |
| CLASS | Communications Link Analysis and Simulation System |
| CLTU | Command Link Transmission Unit |
| CSR | Customer Service Representative |
| DCN | Document Change Notice |
| Dop | Doppler |
| DSMC | Data Services Management Center |
| DSN | Deep Space Network |
| DS-T | Deep Space Terminal |
| EIRP | Effective Isotropic Radiated Power |
| EOS | Earth Observing System |
| EPGS | EOS Polar Ground Stations |
| FCC | Federal Communications Commission |
| GB | Gigabytes |
| GN | Ground Network |
| GNPO | Ground Networks Project Office |
| GNSO | Ground Network Scheduling Operator |
| GSFC | Goddard Space Flight Center |
| ICD | Interface Control Document |
| IP | Internet Protocol |
| IPDU | Internet Protocol Data Unit |

| | |
|---|---|
| IRAC | Interdepartment Radio Advisory Committee |
| ITU | International Telecommunications Union |
| KSC | Kennedy Space Center |
| LEO-T | Low Earth Orbiter-Terminal |
| Mbps | Megabits per second |
| MBps | Megabytes per second |
| METEOSAT | Meteorological Satellite |
| MGS | McMurdo Ground Station |
| MGTAS | Medium Gain Telemetry Antenna System |
| MILA | Merritt Island Launch Annex |
| MOC | Mission Operations Center |
| MSP | Mission Services Program (GSFC Code 450) |
| MTRS | McMurdo TDRS Relay System |
| NASA | National Aeronautics and Space Administration |
| NASCOM | NASA Communications Network |
| NCCDS | Network Control Center Data System (at DSMC) |
| NISN | NASA Integrated Services Network |
| NOM | Network Operations Manager |
| NPD | NASA Policy Directive |
| NSF | National Science Foundation |
| NTIA | National Telecommunications and Information Agency |
| PAO | Performance Analyst Office |
| PDL | Ponce De Leon |
| POC | Point of Contact |
| PTP | Programmable Telemetry Processor |
| RCC | Range Control Center |
| RF | Radio Frequency |
| R-S | Reed-Solomon |
| RSM | Range Support Manager |
| RSO | Range Safety Officer |

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|---|---|
| RTP | Real-time Transmission Protocol |
| SAFS | Standard Autonomous File Server |
| SATAN | Satellite Automatic Tracking Antenna |
| SCAMP | Small Command Antenna on a Medium Pedestal |
| SFCG | Space Frequency Coordination Group |
| SFDU | Standard Formatted Data Unit |
| SGS | Svalbard Ground Station |
| STDN | Spaceflight Tracking and Data Network |
| TCP | Transmission Control Protocol |
| TD | Test Director |
| TDMA | Time Division Multiple Access |
| TDRS | Tracking and Data Relay Satellite |
| TFDH | Telemetry Frame Delivery Header |
| TOTS | Transportable Orbital Tracking System |
| UDP | User Datagram Protocol |
| US | United States |
| UTC | Universal Time, Coordinated |
| UTDF | Universal Tracking Data Format |
| WFF | Wallops Flight Facility |
| WGS | Wallops Ground Station |
| WOTIS | Wallops Orbital Tracking Information System |
| WRC | World Radiocommunication Conferences |
| WSC | White Sands Complex |